ISSN 2308-7269

PEDAGOGICS PSYCHOLOGY

Medical-Biological Problems of Physical Training and Sports

№06/2019

PEDAGOGICS PSYCHOLOGY medical-biological problems of physical training and sports

2019
06

© Iermakov S.S., 2019

Key title: Pedagogics, psychology, medical-biological problems of physical training and sports

Abbreviated key title: Pedagog. psychol. med.-biol. probl. phys. train. sports

ISSN 2308-7269 (English ed. online)

Founders: Iermakov Sergii Sidorovich (Ukraine); (doctor of pedagogical sciences, professor, Department of Physical Education, Kharkov National Pedagogical University).

Certificate to registration: KB 22063-11963P 16.05.2016.

Frequency – 6 numbers in a year.

Journal is ratified Ministry of Education and Science of Ukraine:

physical education and sport: (11.07.2019, № 975, "A" - 24.00.01, 24.00.02, 24.00.03; 017); (13.03.2017, № 374).

pedagogical sciences: (07.05.2019, № 612, "A" - 13.00.02; 011, 014); (07.10.2016 №1222).

Address of editorial office:

Box 11135, Kharkov-68, 61068, Ukraine,

Tel. 38 099 430 69 22

e-mail: sportart@gmail.com

https://www.sportpedagogy.org.ua

Journal is reflected in databases:

1) Web of Science Core Collection [Emerging Sources Citation Index (ESCI)]

http://ip-science.thomsonreuters.com/mjl

DOAJ (Directory of Open Access Journals)

http://www.doaj.org

WorldCat – http://www.worldcat.org

SHERPA/RoMEO – http://www.sherpa.ac.uk

Open Science Directory (EBSCO information services) - http://www.opensciencedirectory.net

PBN (Polish Scholarly Bibliography)

https://pbn.nauka.gov.pl/journals/40688

ERIH PLUS (The European Reference Index for the Humanities and the Social Sciences)

– https://dbh.nsd.uib.no

IndexCopernicus http://journals.indexcopernicus.com

RISC – http://elibrary.ru

Scilit – http://www.scilit.net

ROAD – http://road.issn.org

2) BASE – http://www.base-search.net

Academic Journals Database

http://journaldatabase.org

CORE http://core.kmi.open.ac.uk

Elektronische Zeitschriftenbibliothek

http://ezb.uni-regensburg.de

OAJI – http://oaji.net/journal-detail.html?number=769

3) V.I.Vernadskiy National Library of Ukraine

http://nbuv.gov.ua

Scientific Periodicals of Ukraine

http://journals.uran.ua/olympicedu.org/pps

AcademicKeys

http://socialsciences.academickeys.com/jour_main.php

academia.edu – https://www.academia.edu

Google Scholar – http://scholar.google.com.ua

EDITORIAL BOARD

CONTENTS

2019
06

Identifying control structure of multi-joint coordination in dart throwing: the effect of distance constraint

HosseiniZarch S.H.[1ABCDE], Arsham S.[2ABCDE], Tabatabaei Ghomshe S.F.[3ABCDE], Honarvar M.H.[4ABCDE]

[1] *Department of Physical Education and Sport Sciences, Kharazmi University, Iran*
[2] *Faculty of Physical Education and Sports Sciences, Kharazmi University, Iran*
[3] *Department of Ergonomics, University of Social Welfare and Rehabilitation Sciences, Iran*
[4] *Faculty of Engineering, Yazd University, Iran*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: This study used the uncontrolled manifold (UCM) approach to study joint coordination underlying the control of task-related variables important for success at dart throwing skill. Success at a task can be achieved, in principle, by always adopting a particular joint combination. In contrast, we adopt a more selective control strategy: variations of the joint configuration that leave the values of essential task variables unchanged are predicted to be less controlled (i.e., stabilized to a lesser degree) than joint configuration changes that shift the values of the task variables.

Material: How this abundance of motor solutions is managed by the nervous system and whether and how the throwing in different distances affects the solution to joint coordination was investigated in this study. Our experimental task involved dart throwing to a target under three conditions (standard, short and long distance) that it performed by fifteen dart professional and semiprofessional athletes. The four joint angles of the arm were obtained from the recorded positions of markers on the limb segments. The variability of joint configurations was decomposed into components lying parallel to those sets and components lying in their complement with respect to control of the path of the arm's center of mass and spatial position of the hand.

Results: When performing the task in all three different conditions, fluctuations of joint configuration that affected arm's center of mass and spatial position variables were much reduced compared with fluctuations that did not affect these variables. The UCM principle applied to arm's center of mass and spatial position thus captures the structure of the motor control system across different parts of joint configuration space as the movement evolves in time. Moreover, constraints representing an invariant arm's center of mass or the spatial position structured joint configuration variability in the early and mid-portion of the movement trajectory, but not at the time of throwing. This specific control strategy indicate a target can be hit successfully also by controlling irrelevant directions in joint space equally to relevant ones.

Conclusions: The results suggests a specific control strategy in which changes of joint configuration that are irrelevant to success at the task are selectively released from control. As a result, the method can be successfully used to determine the structure of coordination in joint space that underlies the control of the essential variables for a given task.

Keywords: motor control, degree of freedom, motor redundancy, uncontrolled manifold, skill.

Introduction[1]

Targeting tasks require the coordination of more joint motions than are strictly necessary to specify the arm's position in space. Different combinations of joint angles and muscle activations can be used to reach a given hand position in external space due to the "abundance" of degrees of freedom (DOFs) characterizing the redundancy of the human arm [1]. Having a large number of solutions available to coordinate the arm's motion allows for flexible performance. Yet it has been argued that motor redundancy makes control unnecessarily difficult [1, 2]. Motor redundancy or, when considered more positively, motor abundance [3] makes it possible for multiple variations of joint coordination to be used to achieve a given task performance. Therefore, how the central nervous system (CNS) manages the additional degrees of freedom (DOFs) to achieve reliable and accurate performance is of great interest to movement scientists [4, 5, 6]. That motor abundance is actually used by the central nervous system (CNS) when coordinating the motor elements (such as joints) has been established in numerous studies of a variety of functional tasks [7, 8, 9]. These results are consistent with Bernstein's intuition that task performance typically involves "repetition without repetition" [10, 11].

From a classic control-theory perspective, multi-joint movement in tasks such as pointing, reaching, shooting, or throwing entails two problems. The first problem is one of planning. The appropriate spatial-temporal "shape" of the movement trajectories of important movement components must be specified. The nature of these trajectories also must vary appropriately as conditions of the task vary, for instance, when throwing at different distances is required. The second problem is one of control. Given a plan, the trajectory must be generated in time and a control system must be able to steer the effector system such that appropriate time courses of all involved DOFs are actually realized. These two problems are not

doi:10.15561/18189172.2019.0601

independent of each other. It is not efficient to generate plans that cannot be realized. Conversely, it is not useful to design a control system that can realize movement plans that would never be produced, e.g., plans having no ecological value. It is useful, however, to recognize the two problems as separate aspects at a conceptual level. In the motor control literature, this distinction is often not made explicitly, but it will be important for us here.

A consideration of control as the problem of resolving motor redundancy has led to hypothesized solutions that involve reducing DOFs, including the direct "freezing" of DOFs, or the application of various cost functions to constrain the possible solutions to their coordination [12, 13, 14]. Such solutions have been suggested for the control of reaching tasks, at least implicitly, by a few recent studies [12,15]. Nonetheless, a clear understanding of how the abundant DOFs are constrained to simplify the motor control problem, or are exploited by the control system [3,16] remains elusive.

The researchers proposed a contrasting hypothesis about the control of multiple DOF tasks. This hypothesis, referred to as the uncontrolled manifold (UCM) hypothesis, links the control of a multi-component system to the structure of variability of individual components, allowing the discovery of how the CNS organizes the available complexity to achieve its desired goals [16]. The UCM hypothesis posits a control law linking the coordination of motor components to the stability of important task-related variables—that is, those variables most directly related to the goals of the task, such as the hand's motion in a throwing task. The control law selectively restricts coordination solutions if they lead to changes away from the desired values of important task-related variables. At the same time, the available motor abundance is exploited by allowing an entire range of goal-equivalent solutions to be instantiated, the exact solution depending, for example, on momentary fluctuations of local movement dynamics and external constraints [17, 18]. Support for this hypothesis has been provided by the results of studies of a variety of motor tasks [19, 20]. These results indicate that a range of solutions to motor coordination are typically used to control important task-related variables, even when performance occurs under invariant task conditions [21, 22].

The UCM hypothesis served as the framework of the experimental approach used here to study joint coordination underlying the control of a throwing task. We sought to determine whether unique solutions are typically used when throwing to a given arm position from the different starting location, as the results of research suggested unique solutions are typically used when reaching to a given terminal hand position from the same starting location [15], or whether many solutions to joint coordination are used, as hypothesized by the UCM approach. A number of studies have considered joint coordination [23, 24]. The present study is unique, however, in type skill and its analysis of the structure of joint configuration variability for a 4 DOF arm (shoulder, elbow, wrist and finger joint motion) in relation to the control of important task-related variables. We were particularly interested in understanding how this structure evolved during different phases of the throwing movement. In addition, this study evaluated whether and how the throwing under different distances conditions affected the joint coordination used to control the hand's path.

It is argued that changes in task constraints can influence the magnitude of movement variability observed during task performance [25]. A reduction in coordination variability was also reported, as evidenced by the decrease in standard deviation of continuous relative phase at larger distances. Nonetheless, there was no increase in joint angle variability with distance, which counters previous works [26, 27]. The extent of compensatory behavior between interacting joints is conducted by researchers [26]. This is particularly important as it is the structure, and not the magnitude, of movement variability that identifies its functionality during goal-directed behavior [27]. Consequently, when expressed relative to performance outcome, it could be argued that skilled motor performance is facilitated by a functional bandwidth of movement variability, or, stated differently, a region of optimal functioning. An increased distance has been shown to instigate a reorganization of motor system dynamics. Constraints either allow individuals to explore the available phase-space [28], or alternatively, constrain the human movement system to a narrow range of kinematic solutions [29]. In other words, constraints set boundaries or limits within a dynamical system [30]. The present study is an investigation in joint level and specifically the analysis of the structure of joint configuration variability in relation to the control of important task-related variables while performing dart throwing in different distances.

Methods and Materials

Participants

The data of fifteen healthy, male subjects, 12–53 years of age, who volunteered to participate in this study, were analyzed for this report. All subjects gave written consent, approved by the Dart Association of the Yazd province, before participating. Subject characteristics are presented in Table 1. Four subjects were classified as left-handed and the remaining eleven subjects as right-handed by report of their activities of daily living and throwing history. All subjects used their dominant hand to throw to the target.

Equipment and setup

The standard darts board and tungsten darts were used to perform the throwing. Based on the rules of the World Darts Federation, the height of the center of the dart board and the throwing distance to the dart board were set to 1.73 and 2.4 m respectively, as in the normal darts game.

A two-camera, 120-Hz Optitrack system was used to collect the kinematic data and a calibration for accuracy confirmation was performed before the start of recording (less than 1.0 mm). The cameras were mounted on tripods and were angled to be approximately 1.05 rad apart and positioned so that all reflective markers placed on the

Table 1. Subject age, height, weight, handedness

Subject	Age (years)	Height (m)	Weight (kg)	Dominant Hand
S1	46	180	79	R
S2	53	168	80	L
S3	45	181	78	R
S4	40	168	76	R
S5	38	186	72	L
S6	26	178	68	R
S7	25	175	62	R
S8	25	160	58	R
S9	24	193	77	L
S10	18	175	59	R
S11	24	170	63	R
S12	25	175	62	L
S13	16	175	52	R
S14	15	169	60	R
S15	12	144	40	R

subjects' left side (or right side for left hand subjects) could be seen by both cameras. Three-dimensional coordinates were calculated using PowerMac computers and Motive software. Six 2-cm-diameter reflective spherical markers were attached with adhesive to the skin overlying the following bony landmarks: (a) just inferior to the lateral edge of acromion process, (b) medial epicondyles of the humerus, (c) just distal to ulnar epicondyle (d) carpal bones (e) metacarpal bones (f) proximal phalanx of index.

Dart throwing motion has a little perturbation in a sagittal plane and were analyzed in only a frontal plane in the previous works [31,32]. Besides, in this study, we restrict and analyze the motion to 2-D space in a frontal plane. This restriction is necessary to promote arm motion. For these reasons, we analyze dart throwing motion in a frontal plane.

Subject Calibration

A static calibration posture of the arm was recorded prior to each data collection. This arm calibration was the basis for joint angle calculations in a body-centered coordinate frame. All joint angles were defined as 0º at this calibration posture. The subjects were told to hold their arm perpendicular to the trunk with their thumb facing upwards, the wrist kept in slightly bent backward, the elbow bent to 90 degrees, and shoulder at 90° of flexion. The position was adjusted to meet these criteria by the experimenter.

Experimental procedure

Subjects have sideways stance, with both legs turned in a vertical direction to the target (Z-axis) and shoulder-width apart. The participants were instructed to throw darts in a frontal plane (XY plane). In this study, participants throw at distances of 1.9, 2.4, and 2.9 m. The throwing distance 2.9 m defined as long distance compared to the distance of normal darts game. On the other hand, the throwing distance 1.9 m defined as short distance. Subjects performed 9 dart throws at each throwing distance. Each participant threw darts to aim at the triple area of the dartboard because this point has the highest score in the darts match.

Instructions

Prior to each experiment, subjects were asked to assume the same starting position, which was checked by the experimenter. They were instructed to perform each trial as follows: "After hearing the experimenter's 'go' signal, throw the dart in one continuous motion to the specified target area at a fast, comfortable speed while being as accurate as possible. Try to keep the speed consistent across all trials and movement directions." Subjects were given as many trials of practice as necessary to determine an appropriate speed. In no case was this more than five trials.

Data Processing

Reconstruction of the Marker Positions

Reflective marker identification and reconstruction of the marker positions from the camera views were done using MOTIVE software. Further processing of the kinematic data was performed using customized MATLAB programs. The marker positions were filtered at 5 Hz using a forward and reverse low-pass, 2nd order Butterworth filter.

Definition of Motion

The duration of the motion is different in each throwing motion or among people. In order to compare different trials of dart throwing motion, the throwing data is normalized to 0–100%.

• The start time (0%)

The first time at which the elbow joint angular velocity rises above zero.

• The finish time (100%)

The first time at which the elbow joint angular velocity reduces to zero or less after the start time.

Joint Angle Calculations

Joint angles were obtained based on local coordinate systems defined at each joint in the subject calibration position (Figure 1). Details of the method, which used the algorithms for obtaining the necessary rotation matrices, are described in detail elsewhere [5,33]. The new extension used in this study was to account for scapula motion. This motion was modeled as motion of the rigid body positioned on top of the shoulder with respect to the fixed trunk, and occurring about an axis located at the sterno-clavicular joint. The model was determined to be adequate by having test subjects perform controlled scapular motions. The values of the reconstructed scapular angles were found to be in close agreement with the scapular motions that the subjects performed. The joint angles measured during the throwing task were (a) scapular elevation-depression, (b) elbow flexion-extension (c) wrist flexion-extension (d) finger flexion-extension. The joint angle trajectories were normalized to 100% based on the previously defined trial onset and termination times, using a cubic spline algorithm in MATLAB.

Uncontrolled Manifold

The uncontrolled manifold (UCM) approach provides a method to partition the variance of joint angle combinations (i.e., solutions to joint coordination) across multiple repetitions of a task, performed under identical conditions, into variance components related to the control of important task-related variables. Details of the method as applied to the analysis of a similar task have recently been provided [5]. Briefly, one component of the joint configuration variance represents variations leading to a change in the value of the task-related variable being considered. This component is referred to here as NGEV or non-goal-equivalent variability. The second variance component represents joint configuration variations that are consistent with a stable value of the task-related variable and is referred to as GEV or goal-equivalent variability. The manner in which joint variance is structured with respect to these two components may differ for different task-related variables because the geometric relationship between joint angle space and task-related variable space also differs. If the CNS employs a control law leading to the use of a range of goal equivalent solutions to joint coordination, then the GEV component is expected to be larger than the NGEV component. In contrast, if the CNS were to solve the problem of coordinating multiple DOFs by invoking additional constraints or cost functions, which lead to a unique solution to joint coordination, then both variance components are expected to be very small and close to zero. Note that this analysis requires the comparison of different hypothesized task-related variables under different experimental conditions, because variability is relative. If the NGEV component were found to be quite large compared to the GEV component, then control of the hypothesized task-related variable could be considered less crucial for task success. In this manner, control is directly related to stability of important task-related variables. The first step in applying the UCM approach is to develop a geometric model that links task variable space with the space of joint angles. For a hypothesis about controlling the spatial position of the hand, the d= 2-dimensional (2D) hand position is expressed as a combination of n = 4 joint angles, the joint configuration. Having the geometric model, a linear estimate of all possible joint angle combinations that are consistent with a given hand position can be obtained. This estimate is obtained by calculating the null space of the Jacobian matrix (a matrix relating changes in the joint angle configuration to changes in a task-related variable) [4,5]. In this example, such combinations can be represented as an n-d or two dimensional (i.e., 4-2) surface embedded in the 4-dimensional coordinate frame of the joint angles. We refer to such surfaces as uncontrolled manifolds because, strictly speaking, any combination of joint angles lying within the UCM is consistent with the desired hand position. Thus, there is no need for the CNS

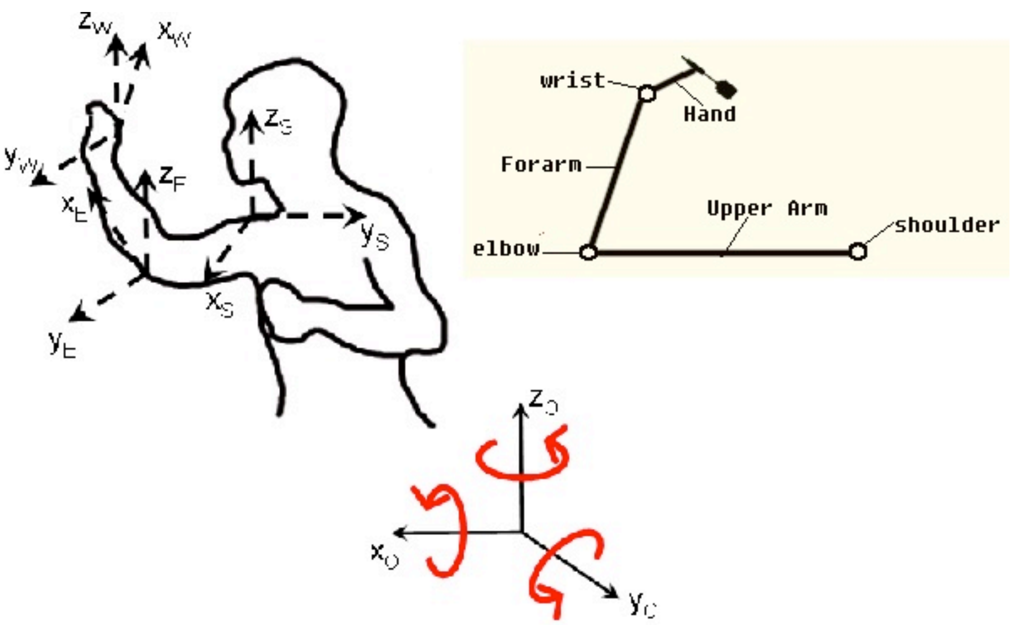


Figure 1. Illustration of the right arm's posture during the procedure to calibrate the arm position for joint angle calculations. From proximal to distal, local coordinate systems are centered at the gleno-humeral, elbow, and wrist joint centers. These are coordinate systems for reconstructing the joint angles. The same arrangements apply to the left arm.

to specify a particular value. In practice, other factors or task constraints may lead to some restriction of that space. At each percentage of normalized time of the hand's path, the average (across trials) joint configuration was used to parameterize the Jacobian. This yielded a sequence of UCMs, one corresponding to each percentage of the hand's path. To analyze how joint configuration variance was structured with respect to the UCMs (i.e., the extent to which that variance lay within the UCM), the vector of 4 joint angles for each trial and at each point in time was projected onto each dimension of the UCM and of a surface orthogonal to the UCM. The variance of each projection across trials yielded the two variance estimates, GEV and NGEV, respectively. (See appendix for mathematical details.) Note that some amount of NGEV is expected because a range of hand (and CM) paths are likely to be consistent with successful task performance. The desired hand path that the CNS attempts to produce in throwing to a target is unknown. Thus, the UCM analysis must be based on an estimate of the desired hand path. For this purpose, we use the hand path that is consistent with the mean joint configuration subjects actually produce across acceptable trials. If the desired hand path is identical to this mean path, then NGEV is expected to reflect noise or error in executing the desired hand path. Most joint configuration variance should be partitioned into GEV. To the extent that this mean path only approximates the desired path, some NGEV will be due to the fact that a range of hand paths is actually acceptable, each hand path being associated with a different sequence of joint angle combinations or UCMs than the UCM representing the mean hand path. At present, we have no way to distinguish between these contributions to NGEV.

Experimental Hypotheses

Because of the nature of the task, it is apparent that the end-effector position will be stabilized at the target for successful performances. We hypothesized that this would be achieved by structuring the variability of joint configurations in a specific way, that is, GEV > NGEV, and this would be the case throughout the movement, not only near the target. This prediction implies that the CNS makes use of available motor abundance to control the hand's position, rather than using a unique solution to joint coordination. Note that the latter strategy could also be consistent with a stable path and terminal position of the end-effector. We also evaluated how the joint variance was structured to control the arm's center of mass (CM) position. The researchers suggested that the arm's CM was more controlled than the hand's trajectory when subjects performed a non-redundant reaching task [34]. Evidence against this hypothesis was presented in a study of a multi-DOF pistol-shooting task [5] and pointing task [6]. Here, we sought to determine if the full path of the center of mass was also stabilized for the two-dimensional, redundant throwing task and, if so, whether this was accomplished by a similar or stronger use of goal-equivalent joint combinations than for the control of the hand path.

We also hypothesized that the variance of joint configurations would be increased when targeting in the different throwing conditions. This prediction was based on two factors. A previous study of the coordination of a postural task indicated that performance under challenging task conditions led to an enhanced use of goal equivalent joint configurations [35]. Thus, GEV would be expected to increase if a similar effect were to result from throwing in the short and long distances. Second, probably performance under challenging task conditions induce to an inaccuracy of the sensorimotor representation of the target [36]. Such uncertainty should lead to more inconsistency from trial to trial in selecting an appropriate joint configuration needed to produce a reliable hand trajectory and, thus, to an increase in NGEV compared to throwing in the standard condition. Thus, both components were expected to increase. It was of interest to determine which predicted effect was strongest and whether it depended on the skill of the arm used to perform the throw.

Dependent Variables

Components of Joint Variance. The dependent variables of primary importance to this study were the two components of the variance of the joint configuration, GEV and NGEV, calculated at every 1% of the movement period with respect to the 3D position of the pointer-tip and the 3D position of the arm's CM. These variances were then averaged and evaluated with respect to the experimental hypotheses over the periods of 0–20% (early phase), 30–50% (middle phase), and 70–90% (late phase) of the movement path, as well as at movement termination (100%).

Additional Kinematic Variables

The following kinematic variables were also examined:

1. Movement time: duration from the onset to the end of the movement;
2. Time to peak velocity: Peak velocity was calculated by taking the first derivative of the arm's path using central differences method. Then, an automatic algorithm was applied to find the time of the maximum velocity using MATLAB. The time to peak velocity was expressed as percentages (%) of the total movement time.
3. Path variability of the end-effector and CM: This was calculated by taking the standard deviation of the end-effector and CM's position at each percentage of the normalized movement across all trials, and then averaging across 0–20%, 30–50%, and 70–90% of the movement.

Independent Variable

The independent variables directly manipulated in the experiment were the arm with which subjects threw (right and left) and the distance conditions (short, standard and long distances).

Statistical Analysis

The hypotheses were analyzed with repeated measure analyses of variance (ANOVA) using the SPSS statistical package. Separate analyses were performed to analyze the effects of independent variables on measures related to the paths of the end-effector and of the arm's CM. Factors in the ANOVA included the independent variables and the components of variance (GEV and NGEV). Each ANOVA was performed separately on data for three different phases of the movement (early, middle, late).

Results

Movement time

No subject had difficulty completing the task, keeping the movement speed relatively consistent across different throwing conditions (Table 2). Movement time variability across trials was also not significantly different between experimental conditions (P>0.05). Individual differences in movement time were evident, however: the range of movement times, however, the range of movement times was from 2.2 to 2.7.

Below, general features of the movement kinematics are presented, followed by the main results on joint coordination and their relation to throwing performance.

Time to Peak Velocity

The total movement time was similar across conditions (Table 2), while the time to peak velocity, or the acceleration phase, expressed as the percentage of the total movement time, depended on the availability of throwing distances (Table 2). The arm accelerated faster when throwing in the long distance than with the short and standard distance ($F= 6.74$, $p<0.05$). In other words, the mean peak velocity of movement was smallest for starting positions closest to the target (short distance) and largest for the conditions initiated from the 2.9 m distance ($F= 39.72$, $p<0.05$). Moreover, the throwing time was larger when throwing in the long distance than with the short and standard distance ($F= 5.38$, $p<0.05$).

Joint kinematics

Figure 2 shows the mean path of each joint angle of the arm of one randomly chosen subject. Note the variability of the trajectories across trials. The scapula and forearm motions exhibited the smallest movement compared to other joints of the hand. The finger motions exhibited the largest excursion across all experimental conditions. Joint motions were most similar across all trials and subjects for all experimental conditions, while individual differences were apparent for joint angles variability. The average joint excursions of the four joint angles that contributed to throwing motion across all trials and subjects are shown in Fig. 3.

Figure 4 presents the range of excursion (maximum-minimum) observed across trials for the four joint angles, averaged across the fifteen subjects for each experimental condition. All angles exhibited variability across trials. Finger and wrist angles exhibited the most variability, while the magnitude of variability was more dependent on the condition. Thus, contributions to joint configuration variability were distributed along the kinematic chain, although variability was clearly greatest at the most distal segment.

For horizontal and vertical positions of finger, the results show the joint variability at all throwing distances were statistically higher than ones for wrist, elbow and shoulder ($p<0.05$). Thus it was elucidated that throwers coordinate shoulder, elbow, and wrist joints in order to achieve a specific kinematics of finger position during dart throwing motion. In the case of wrist and elbow for either horizontal or vertical direction, the degrees of joint coordination at all throwing distances were statistically higher than one for shoulder ($p<0.05$). For vertical position of wrist, the degree of joint coordination at each throwing distance were statistically higher than one for elbow ($p<0.05$).

The Structure of Joint Coordination and Task Variable Control

Figures 5 and 6 illustrate for all subject the components of joint configuration variability per DOF that lie parallel (||UCM) and perpendicular (⊥UCM) to the UCM for hypotheses about spatial position of the hand (Fig. 5) and movement path of the arm's CM (Fig. 6). For the hypothesis about spatial position of the hand, ‖UCM >> ⊥UCM at 70% of the movement path for all experimental conditions. Just prior to the mid-point of the movement, ⊥UCM was more than ||UCM, especially for the long condition. However, thereafter ⊥UCM is less than ||UCM. Thus, there is evidence that the central nervous system (CNS) constrains joint variability along directions that keep the spatial position of the hand invariant near the mid-point of the movement while allowing joint configuration fluctuations in directions that do not affect this position. Note, however, that the difference ||UCM–⊥UCM for the hypothesis about spatial position is often smaller and less

Table 2. The Mean Movement Time and Time to Peak Velocity for Each Experimental Condition

Movement variables	Distance Conditions Standard	Short	Long
Movement time (s)	2.5	2.2	2.76
Time to throw (%MT)	75.38*	70.53*	82.91*
Time to peak velocity (%)	40.35*	32.28*	43.69*

*Significant difference at *p*<0.05

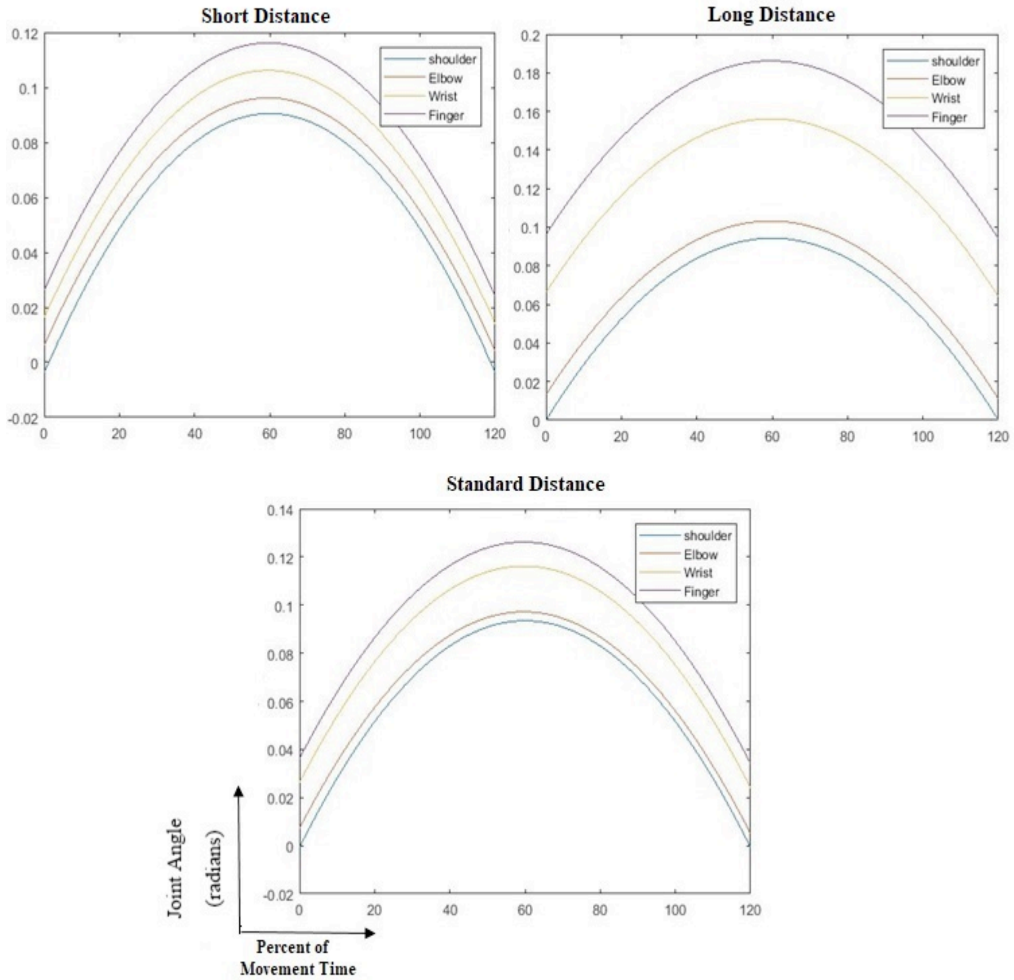


Fig 2. Mean joint excursions for arm calculated across all trials for a representative subject's data in different throwing conditions.

consistent across conditions than for the hypothesis about center-of-mass position.

Results of the ANOVAs were consistent with this pattern of differences. For the control hypothesis about spatial position, significant differences between ⊥UCM and ||UCM were present (F=97.4, P<0.005). The magnitude of this effect was dependent also on the part of the movement cycle examined (F=6.42, P<0.005) and on the experimental conditions (F=8.29, P<0.005). The first interaction was due to larger differences between the variability components at the middle phases and thereafter than were present earlier in the movement trajectory (Fig. 5). Nonetheless, ⊥UCM was greater than ||UCM for portions of the trajectory (10 and 50 %), and for long distance condition (F=5.38, P<0.05). The magnitude of the difference between ⊥UCM and ||UCM was approximately the same for standard and short distances conditions, where the differences were smaller overall than for the other condition (F>8.71, P<0.05). This smaller difference was due to the fact that variability parallel to the UCM was smaller than for the other condition.

For the control hypothesis about the arm's center of mass, the overall difference between ⊥UCM and ||UCM was significant (F=59.41, P<0.01), as was the interaction of this factor with the portion of the trajectory (F=11.36, P<0.01). There were significant effects involving experimental conditions. At both 10% and 50% of the movement trajectory, ⊥UCM was more than ||UCM for long distance condition (F=7.84, P<0.05). The difference between ⊥UCM and ||UCM was lesser in the short and standard distance conditions (F<8.17, P<0.05). While in the long distance ⊥UCM was significantly larger than ||UCM at 10% and 50% of the trajectory (F=38.75, P<0.05), ⊥UCM was significantly in short and standard distance conditions approximately equal to ||UCM (F=14.57, P<0.01). In fact, beyond 60–70% of the trajectory, ⊥UCM was less than ||UCM for the short and long distances, suggesting that joint configuration space was structured in a way specific to the position of the center of mass near the time of throwing, while this was not the case for the standard distance condition.

To facilitate a more direct comparison of the two hypotheses, the ratio ||UCM to ⊥UCM was examined. A significant effect of condition (F=5.73, P<0.05), percentage of the trajectory ($F_{2,16}$=6.00, P<0.05), and hypothesis (F=48.82, P<0.01) was found, as well as a significant interaction between the hypothesis and both experimental condition (F=4.93, P<0.01) and percentage of the trajectory (F=27.35, P<0.01). Simple main effects revealed that the value of this ratio was larger for the

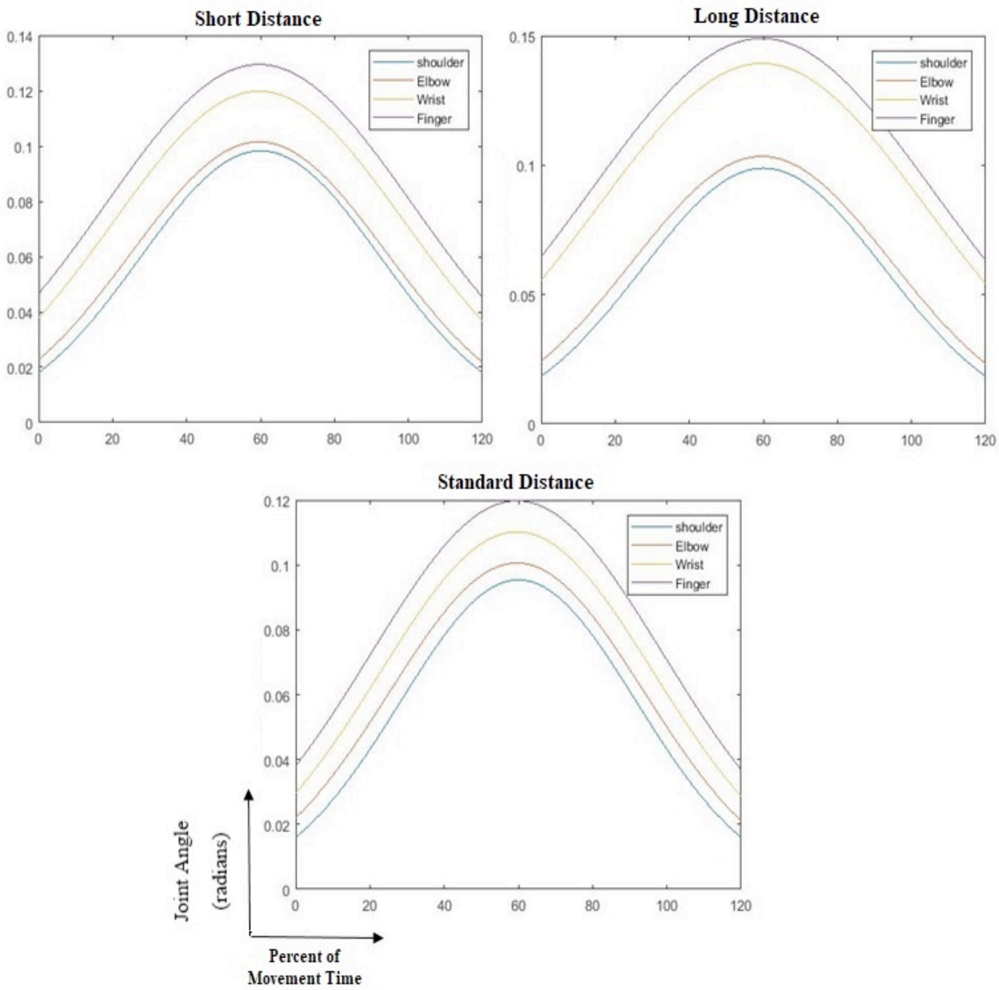


Fig 3. The total joint excursion, averaged across all trials for each subject and then across subjects, for each of 4 joint angles in different throwing conditions.

hypothesis about arm's center of mass than for the other hypothesis at approximately all points examined in the trajectory (F=12.67, P<0.05). The ratio ||UCM to ⊥UCM was significantly less than one for both hypotheses at the beginning of the movement trajectory. However, that was the opposite, at the middle phase and later.

We also examined how joint configuration variability parallel to the UCM was distributed along each dimension of the UCM. For the hypothesis about spatial position of the hand, the UCM has two dimensions (i.e., four joint angles – two orientation angles). Figure 7 provides an indication of how this variability, expressed as the square root of the individual variance component, is distributed along each dimension of the UCM at each 20% of the movement trajectory. This figure reveals that the variability is distributed somewhat non-homogeneously across dimensions. The dimension of the UCM exhibiting the largest variability varies somewhat across the movement trajectory, although there is relative consistency across conditions for a given point in the trajectory. Unfortunately, these variability components cannot be related directly to the variability of individual joints, because the dimensions of the UCM are not aligned with but cut across the seven axes in joint space.

Discussion

One objective of the present study was to identify the structure of the joint control system for a skilled motor task, namely, dart throwing to a target. A requirement for successful throwing performance is the production of a stable hand path. There are theoretically many ways to achieve this stabilization. We found that control of the hand's movement path and that of the CM was achieved through the use of a range of goal-equivalent joint combinations. Our results suggest that only certain directions in the space of joint configurations are restricted—that is, those leading to a change in the value of important task-related variables—while a range of goal-equivalent joint configurations are actually utilized. This finding is consistent with the results of studies of the coordination of a number of very different tasks [37]. Unlike those tasks, dart throwing is ballistic and targeting motor skill which depend more strongly spatial position of the hand and arm's center of mass. We found that these task variables structured the joint control system throughout the movement, not only near the time of throwing and terminal phases of the movement.

We Examined the spatial position of the hand and

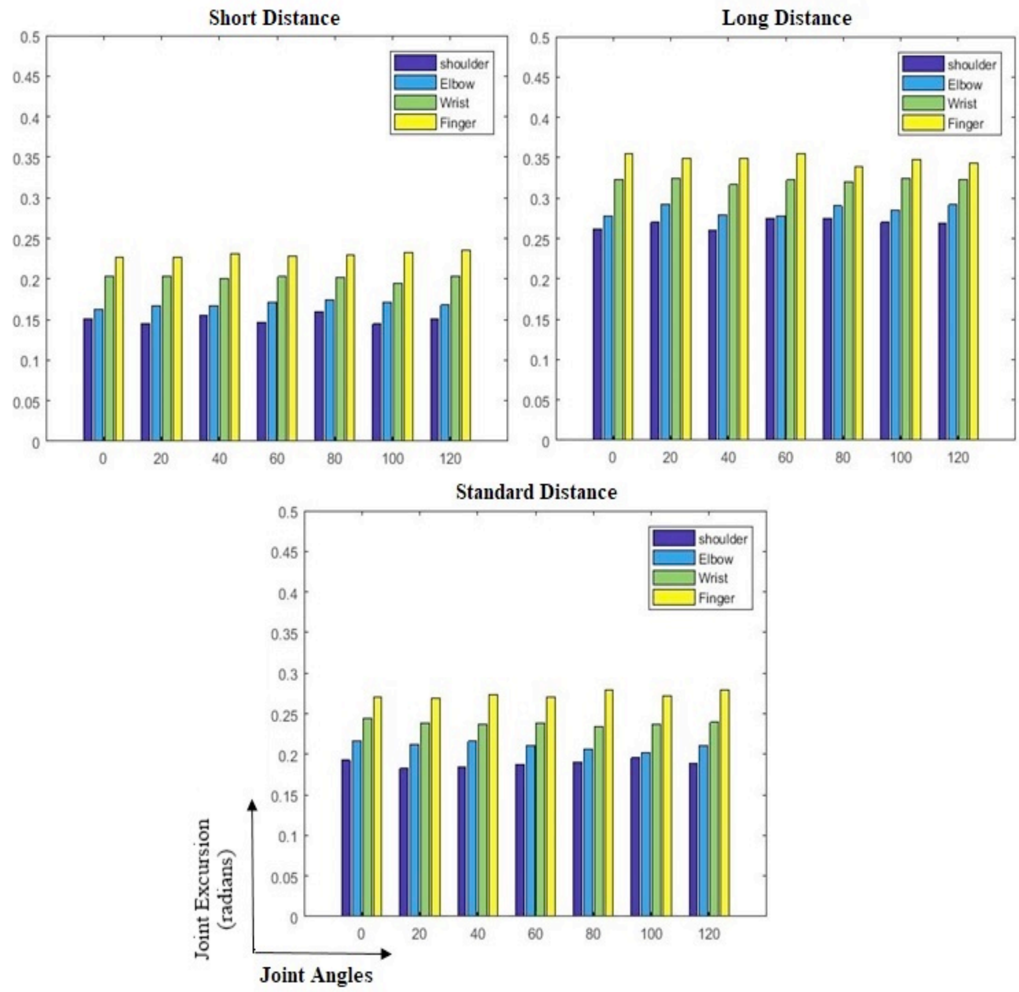


Fig 4. The range of joint excursion across all trials (maximum-minimum excursion) of each experimental condition for each joint angle.

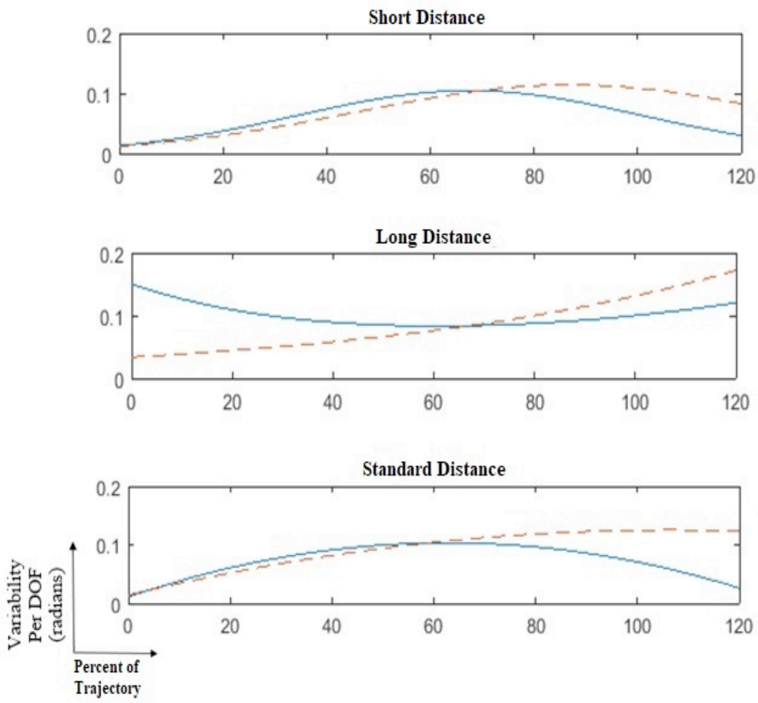


Fig 5. Mean (across subjects) of components of joint configuration variability per DOF lying parallel (thin dashed line) and perpendicular (thick solid line) to the uncontrolled manifold for the hypothesis of controlling the spatial position of the arm in different throwing conditions.

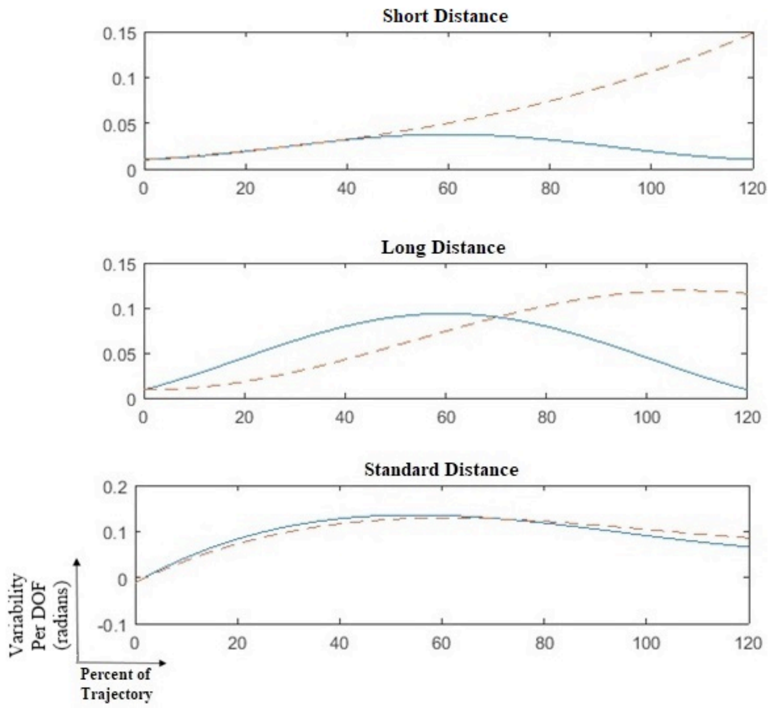


Fig 6. Mean (across subjects) of components of joint configuration variability per DOF lying parallel (thin dashed line) and perpendicular (thick solid line) to the uncontrolled manifold for the hypothesis of controlling the arm's center of mass position in different throwing conditions.

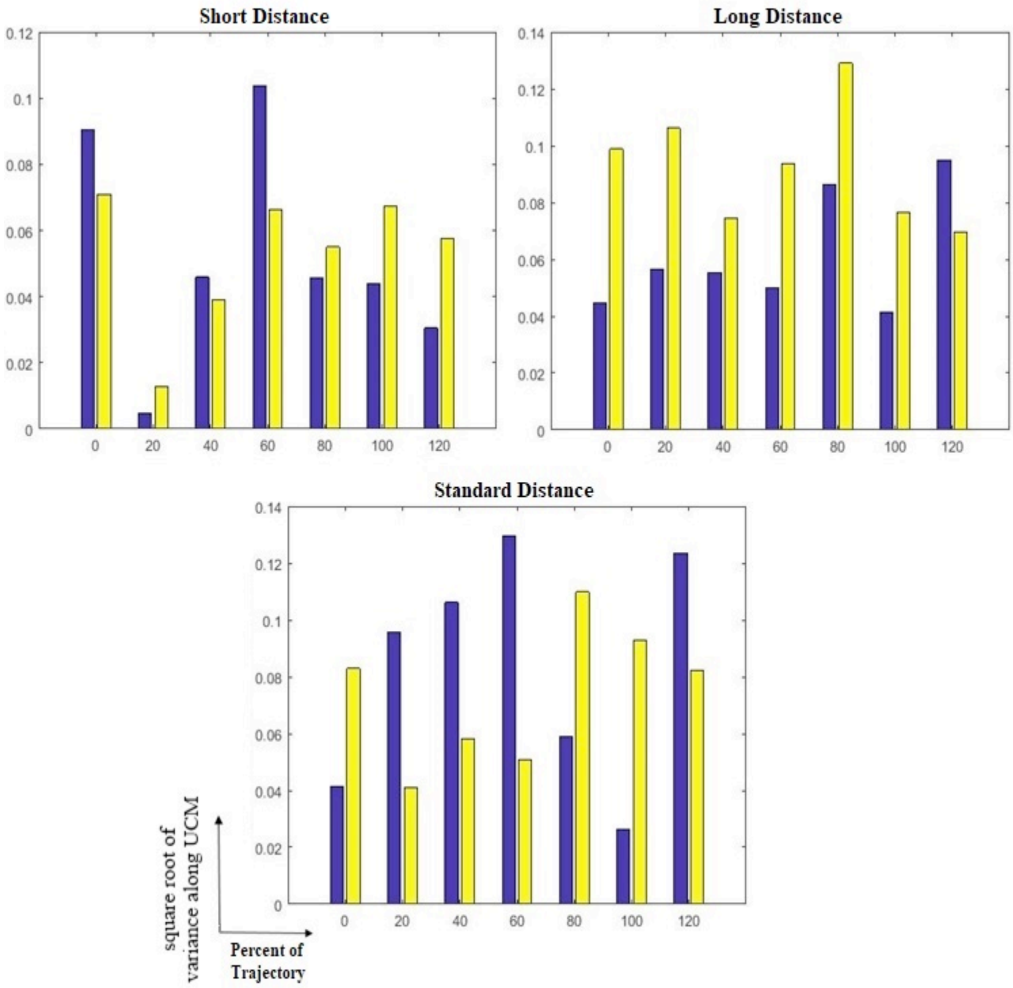


Fig 7. The components of joint configuration variability parallel to the UCM along each of its dimensions for the hypothesis about controlling arm's spatial and center of mass positon. The two components are represented by bars of different shading in the same order at each 20% of the movement trajectory for different throwing conditions.

arm's center of mass as task variables that might structure control in joint configuration space. We examined spatial position to consider the possibility that subjects might attempt to shoot from the same final hand position to reduce variability of one variable that might affect task success [5]. The center of mass was considered, in part, because it is especially important to the movement dynamics. In addition, the results of a study of reaching by researchers [5,34] were used to argue that center of mass position is more controlled than end-effector position in such tasks. In each case, those changes of joint configuration that would change the current value of a task variable are assumed to be more constrained than changes that do not change the current value of the task variable if that variable is essential to successful task performance. Thus, the variability of joint configuration from trial to trial at corresponding points in time during a movement is analyzed as a measure of stability, decomposing it into its component that keeps the task variable unchanged (fluctuations parallel to the UCM) and its component that changes the value of the task variable (fluctuations perpendicular to the UCM). A completely different style of control could be used, however, i.e., if joint configuration variability was severely constrained in all directions. This would indicate that specific postural states of the arm and their sequences were specified to achieve the goal. An advantage of a UCM control strategy (i.e., freeing certain directions in joint configuration space from control) may be a reduction of unnecessary perturbations [5]. That is, applying control signals to the muscles to limit certain joint combinations leads to additional interactive torques because of mechanical coupling of the movement segments. These additional interaction torques would need to be compensated to preserve a particular kinematic signature [38].

The UCM analysis for the two hypotheses concerning the arm's CM and spatial position of the hand did not reveal structure in joint configuration space to the same extent. In both cases, variability per DOF perpendicular to the UCM was larger than variability per DOF parallel to the UCM, but only early in the trajectory. This may indicate that task constraints such as control of the position of the end-effector and of the center of mass contribute more strongly to the structure of the control system the later aiming phase compared with the early in the transport phase. In the final phases of the movement trajectory and for both the hypotheses in the all conditions (Except for the short distance condition in the hypothesis about arm's CM), both variability components decreased. The decrease in joint configuration variance as the target was approached and at movement termination may reflect additional control action taken by the CNS to help ensure movement accuracy. Note that, despite this overall reduction in joint configuration variability, goal-equivalent variability was still significantly larger than NGEV. However, the stability of the hand path was ultimately preserved as shown by the reduction of overall joint configuration variability and the enhanced structure of GEV>NGEV when the hand decelerated toward the target. This corroborates that stability of task-related variables is defined as its resistance to transient perturbation. Thus, a temporary disturbance, like a stronger effect from inter-segmental dynamics, eventually will be resolved if this variable is important for task success.

For the hypotheses about the arm's CM and spatial position of the hand, we found that variability per DOF parallel to the UCM was substantially and significantly less than variability perpendicular to the UCM. This was true from very early in the movement trajectory and only in the long distance condition, but beyond 60% of the trajectory, variability parallel to the UCM was greater than variability per DOF perpendicular to the UCM. Thus motor control system is highly structured in joint space in a way that is captured by the variance of spatial position of the hand and arm's CM, only in the early of the movement trajectory: those changes of arm configuration from trial to trial that change the spatial position and arm's CM are resisted much less than those changes of arm configuration that do not change that position. For the hypotheses about the arm's CM and in the short distance condition, at the early in the movement trajectory, variability parallel and perpendicular to the UCM was equal. This lack of a difference resulted both from increased variability perpendicular to the UCM and decreased variability parallel to the UCM. Another reason may well be that the motor control system is structured in joint space in a way that is the hypothesized invariance of spatial position of the hand and arm's CM. However, at the middle and terminal phases of the movement trajectory, variability parallel to the UCM was larger. This can be due to the coordination of motor components to the stability of important task-related variables. For both the hypotheses in the all conditions (Except for the short distance condition in the hypothesis about arm's CM), early in the movement path, variability parallel to the UCM was less than variability per DOF perpendicular to the UCM. This apparently leads to a limitation of the motor equivalent solutions available for throwing (i.e., ||UCM or GEV), rather than increased variability of the arm's CM and spatial position of the hand to the target (i.e., ⊥UCM or NGEV).

The variability perpendicular to the UCM determines the variability of the spatial position of the hand and arm's CM. That variability must remain within particular bounds in order to accomplish the task. This does not imply, however, that the variability parallel to the UCM must necessarily be larger. In fact, the variability parallel to the UCM simply does not matter for the accomplishment of the task. It may be larger than, equal to, or smaller than the variability perpendicular to the UCM. The fact that fluctuations of joint configuration conserve the arm position relative to the target, even while the hand is not actually aiming at the target, further illustrates that the control structure discovered here is not a trivial consequence of success at the task. The increase in the use of goal-equivalent joint combinations that we observed when subjects threw in the different distances could have been a compensatory strategy used to help reduce potentially disturbing internal perturbations (due to interaction torque that would be generated by unnecessary control action).

The magnitude of the difference between ||UCM and ⊥UCM was significantly smaller on average when the throwing was performed in standard distance compared with the other two conditions. However, this result was due to reduced variability parallel to the UCM after the mid-point of the movement compared with the other three conditions, and not to differences in variability perpendicular to the UCM. If the decrease and/or increase in distance had introduced errors in the timing of the arm trajectory across trials, then the basis for our trial alignment procedure, prior to time normalization, would have been violated. However, this would have resulted in greater variability perpendicular to the UCM. Thus, our assumption is reasonable and conservative with respect to the hypotheses. (For example, with timing errors, the joint configuration at 50% of the arm trajectory for different trials could be associated with events occurring slightly before, slightly after, or at the time of peak velocity and, thus, with different UCMs. Because the UCM on which the analysis is based is estimated from the mean joint configuration at the same percentage of the trajectory for all trials, under the assumption of consistent timing of the task variable's trajectory, such timing errors would lead to increased variability perpendicular to the UCM. Timing variability of the joint trajectories, i.e., one joint getting ahead or behind another joint from trial to trial, could contribute to increased variability either parallel or perpendicular to the UCM. Although we cannot determine this effect from the present data, there is no reason to expect that the probability of joint timing errors contributing to one variability component would be greater than to the other.

Joint configuration variability was distributed along all dimensions of the UCM for the hypotheses about controlling the arm's CM and spatial position of the hand, although this distribution was nonhomogeneous. As already noted, there is no direct correspondence between dimensions of the UCM and specific joint angles. The fact that joint configuration variability is distributed along all dimensions of the UCM indicates that all joints contributed to the motor equivalent solutions suggested by the UCM analysis (i.e., for stabilizing arm trajectory).

Conclusion

In the current study, the geometric model captures the relationship between joint configurations and the task-related variables only at the level of kinematics. Moreover, movement dynamics, which were not formally considered in this analysis, must play an important role in determining the control structure of such movements. This may be especially important in the early stage as the limb is accelerated. The finding that center of mass position structured joint configuration variability in a similar way to spatial position early in the movement is consistent with this importance. Nonetheless, although movement dynamics and passive biomechanics must influence the control of this task, the contribution of such constraints is unlikely to be as important in such targeting tasks as perceptual-motor constraints posed by the external target. This argument is supported by the finding that, despite starting from three different initial arm positions that involved different muscle lengths, a very similar structuring of the joint configuration variability was observed. In addition, it is difficult to explain how dynamics might account for the fact that the arm and end-effector trajectory to the target structured joint configuration variability in a particular way even early in the movement trajectory.

Our observation that the arm position structures variability in joint space in the way predicted by the UCM principle is evidence for a particular control strategy compatible with the task (out of an ensemble of other possible strategies). This particular control principle consists of releasing from control (to a degree) those DOFs that are not essential to task success. It is important to realize that it is not individual joint angles that are released from control, but particular combinations of joint angles. Because all joint angles are mechanically coupled, releasing from control particular combinations of joint angles requires, in general, that coordinated signals are sent to all joints. Thus, release from control is an active strategy, not just a trivial failure to send command signals to particular joints.

The nonessential DOFs are released throughout the entire trajectory, even while the arm is not actually aiming to the target. During the movement, the arm configuration goes through different regions of configuration space. In these different regions, the UCM is, in general, quite different. Therefore, the exact combination of joint angles that are released from control varies along the trajectory. It actually provides a common principle that predicts in which different regions of joint configuration space DOFs are released from control. Why would it be a useful strategy to release from control some combinations of kinematic DOFs to achieve success in a difficult task? When the DOFs problem is invoked at the planning level, the computational load to specify the time course of many variables is sometimes viewed as the problem. Thus, reducing the number of DOFs that require planning makes the problem more tractable.

What does the UCM principle imply for the problem of planning multi-joint movements? A direct experimental implication concerns the reproducibility of trajectories that define the space of the UCM; in our case, the joint position configuration. If postural states of a control variable that have reduced stability with respect to particular directions in joint space are passed through during the movement, then the joint configuration obtained at the end of the movement (or at any intermediate point, for that matter) may not be perfectly reproducible. Depending on the movement path, different types of perturbations may have been encountered along the trajectory, which may have led to varying shifts of the joint configuration along the UCM through which the trajectory passes. As a result, the final joint configuration may depend on the starting position of the effector system.

There are two ways in which release from control could be achieved. One possibility is that the viscoelastic properties of the motor apparatus are tuned to the task, reducing the effective stiffness of the arm configurations in the task-irrelevant directions in joint space and/or increasing stiffness in the directions in joint space along which arm position changes during movement. Such a control principle would, no doubt, be quite complex in view of the large number of DOFs and the prevalence of multi-joint muscles. This also makes it quite difficult to test such an account, as the stiffness matrix is very difficult to measure in this system during the act of shooting.

An alternative account would assume that release from control arises from higher levels of motor control and planning. Essentially, planning would specify entire UCMs and their evolution in time, rather than specific joint trajectories. In this way, the nervous system may make use of redundancy to provide flexibility of movement patterns while preserving the stability of important task variables. The problem of motor redundancy, then, should be considered not as a problem but as an inherent part of the solution for the problem of multi-joint coordination. In either account, what must be learned or developed in order for skill to emerge is the task-specific structure of the motor control system in joint configuration space.

Applications and limitations

According to the results of the research, in order to achieve precision control, individuals must stabilize a body part position which is close to the finger in throwing motion. Moreover, the nervous system makes use of redundancy to provide flexibility of movement patterns while preserving the stability of important task variables. This ability of the controller to use the flexibility may be impaired in people with motor disorders, leading to a diminished capability to take advantage of the flexibility. The routes to applying UCM approaches to clinical studies face a number of challenges. In particular, although identification of elemental variables may be relatively straightforward in people who are healthy, this essential step in the UCM analysis may pose problems in patients with neurological disorders whose ability to change apparent elemental variables independently of each other may be impaired. The present study has used analysis of variability across consecutive trials at a particular task to quantify the 2 components of variance. However, it may be unrealistic to expect patients with neurological disorders to be able to perform many trials using the same control strategy. Development of the UCM method so that it can be used for analysis of single trials or small groups of trials is urgently needed.

The results of this study indicated that the longer and shorter throw induced the new motor control strategy of precision control and force generation. The authors' future research will measure and analyze dart-throwing motion on different conditions, changing a weight of dart arrows, foot stance or arm path. In this study, the UCM analysis was applied to dart throwing motion in order to investigate the precision control ability by joint coordination. In future work, we need to combine the "muscle synergy," which is the motor primitive for redundant muscle; and the "motor synergy," which is a neural mechanism for generating joint coordination. Although based on the available equipment, a two-camera system was used to collect the kinematic data, it is imperative to use more cameras for more accurate recording and a more detailed review of the orientation of the darts to the target.

Appendix: Uncontrolled Manifold Analysis

The UCM approach allows the variance of joint angle combinations (i.e., solutions to joint coordination) across multiple trials, performed under identical conditions, to be partitioned into two variance components. Unlike a principal components analysis, where partitioning of variances is without reference to a priori control hypotheses, the UCM method partitions the joint configuration variance with respect to specific control hypotheses about task-related variables, such as the direction of the pointer-tip's movement. One component of the partitioned joint configuration variance is inconsistent with a stable value of the hypothesized task-related variable. The second variance component represents goal-equivalent solutions to the value of the task-related variable—that is, multiple solutions to joint coordination that preserves the stability of the task-related variable with respect to which the partitioning is performed. Thus, the approach allows for the identification of different styles of control of important task-related variables. The manner in which joint variance is structured with respect to these two components may differ for different task-related variables because the geometric relationship between joint angle space and task-related variable also differs. In this study, the component of variance that affects the value of a task-related variable is referred to as NGEV (non-goal-equivalent variability), while the component that is consistent with a stable value of a task-related variable, (i.e., does not affect the value of that variable) is referred to as GEV (goal-equivalent variability). (See Methods and Materials for details regarding the interpretation of various differences between GEV and NGEV.)

Formally, a forward kinematic model is used to link the joint angles to the vector representing values of the task-related variable. The model describes each value of the hypothesized task-related variable, r, in terms of joint angles θ. The configuration of the arm is described by a set of n-joint angles. In this study, the dimension of n=4. For determining how variability in joint angle space is structured with respect to hypotheses about controlling the spatial position of the hand and the position of the arm's center of mass, the task-related variable has d=2 dimensions. The effector system is redundant (n>d), therefore, with respect to motions of the hypothesized task-related variables.

The statistical analysis of joint configuration variability requires that the UCM be approximated linearly. The linear approximation is performed at each time slice of the trajectory, around a postural state or reference joint configuration θ^0. The postural state is estimated by calculating the mean joint configuration across trials of identical condition at each time slice. The linearized forward kinematics around each reference configuration, $\underline{\theta}^0$, is

$$\underline{r} - \underline{r}^0 = J(\underline{\theta}^0) \cdot (\underline{\theta} - \underline{\theta}^0)$$

where r^0 is the value of the task-related variable corresponding to the reference configuration of joint angles, $\underline{\theta}^0$. $J(\underline{\theta}^0)$ is the d × n Jacobian matrix computed at each time slice for the reference configuration. In this case, the UCM is approximated by the null-space of the Jacobian matrix, $J(\underline{\theta}^0)$. The null space represents those joint angle combinations that leave the task-related variable unaffected. The null-space is spanned by basis vectors ε_i, solving

$$0 = J(\underline{\theta}^0) \cdot \underline{\varepsilon_i}$$

There are n-d basis vectors, so that the null-space has n-d dimensions. The ε_i vector is computed numerically at each time slice using MATLAB. Then, at each time slice, deviations of the vector of joint angles of each trial from the vector of mean joint angles, $\theta - \underline{\theta}^0$, are resolved into their projection onto the null space:

$$\underline{\theta}_{\parallel} = \sum_{i=1}^{n-d} \left(\underline{\varepsilon_i^T} \cdot (\underline{\theta} - \underline{\theta}^0) \right) \underline{\varepsilon_i}$$

and the component perpendicular to the null-space:

$$\underline{\theta}_{\perp} = \left(\underline{\theta} - \underline{\theta}^0\right) - \underline{\theta}_{\parallel}$$

The amount of variability per DOF within the UCM is estimated as:

$$\sigma_{\parallel}^2 = (n-d)^{-1} \cdot (N_{trials})^{-1} \cdot \sum_{trials} \underline{\theta}_{\perp}^2$$

where $\theta_{\parallel}^2$ is the squared length of the $\underline{\theta}_{\parallel}$ deviation vector lying within the linearized UCM. Analogously, the amount of variability per DOF perpendicular to the UCM is estimated as:

$$\sigma_{\perp}^2 = (d)^{-1} \cdot (N_{trials})^{-1} \cdot \sum_{trials} \underline{\theta}_{\perp}^2$$

As noted earlier, these variance components are referred to as GEV ($\sigma_{\parallel}^2$) and NGEV ($\sigma_{\perp}^2$) in the body of this article.

Conflict of interests

The authors declare that there is no conflict of interests.

References

1. Bernshtein NA. *The Co-Ordination and Regulation of Movements*. Oxford: Pergamon Press; 1967.
2. Steenbergen B, Marteniuk RG, Kalbfleisch LE. Achieving Coordination in Prehension: Joint Freezing and Postural Contributions. *J Mot Behav*. 1995;27(4):333- 48. https://doi.org/10.1080/00222895.1995.9941722
3. *Gelfand IM, Latash ML. On the problem of adequate language in motor control. Motor* Control. 1998;2(4):306- 13. https://doi.org/10.1123/mcj.2.4.306
4. Scholz JP, Schoner G. The uncontrolled manifold concept: identifying control variables for a functional task. *Exp Brain Res.* 1999;126(3):289- 306. https://doi.org/10.1007/s002210050738
5. Scholz JP, Schoner G, Latash ML. Identifying the control structure of multijoint coordination during pistol shooting. *Exp Brain Res.* 2000;135(3):382- 404. https://doi.org/10.1007/s002210000540
6. Tseng Y, Scholz JP, Schoner G. Goal-equivalent joint coordination in pointing: affect of vision and arm dominance. *Motor Control*. 2002;6(2):183- 207. https://doi.org/10.1123/mcj.6.2.183
7. Freitas SM, Scholz JP, Latash ML. Analyses of joint variance related to voluntary whole-body movements performed in standing. *J Neurosci Methods*. 2010;188(1):89- 96. https://doi.org/10.1016/j.jneumeth.2010.01.023
8. Latash ML. The bliss (not the problem) of motor abundance (not redundancy). *Exp Brain Res*. 2012;217(1):1- 5. https://doi.org/10.1007/s00221-012-3000-4
9. Togo S, Kagawa T, Uno Y. Uncontrolled Manifold Reference Feedback Control of Multi-Joint Robot Arms. *Front Comput Neurosci.* 2016;10: 69. https://doi.org/10.3389/fncom.2016.00069
10. Zhou T, Solnik S, Wu YH, Latash ML. Unintentional movements produced by back-coupling between the actual and referent body configurations: violations of equifinality in multi-joint positional tasks. *Exp Brain Res*. 2014;232(12):3847- 59. https://doi.org/10.1007/s00221-014-4059-x
11. Gera G, Freitas S, Latash M, Monahan K, Schoner G, Scholz J. Motor abundance contributes to resolving multiple kinematic task constraints. *Motor Control*. 2010;14(1):83- 115. https://doi.org/10.1123/mcj.14.1.83
12. Cruse H, Bruwer M, Dean J. Control of Three- and Four-Joint Arm Movement: Strategies for a Manipulator With Redundant Degrees of Freedom. *J Mot Behav*. 1993;25(3):131- 9. https://doi.org/10.1080/00222895.1993.9942044
13. Schwartz AB, Moran DW. Arm trajectory and representation of movement processing in motor cortical activity. *Eur J Neurosci.* 2000;12(6):1851- 6. https://doi.org/10.1046/j.1460-9568.2000.00097.x
14. d'Avella A, Fernandez L, Portone A, Lacquaniti F. Modulation of phasic and tonic muscle synergies with reaching direction and speed. *J Neurophysiol*. 2008;100(3):1433- 54. https://doi.org/10.1152/jn.01377.2007
15. Desmurget M, Grea H, Prablanc C. Final posture of the upper limb depends on the initial position of the hand during prehension movements. *Exp Brain Res*. 1998;119(4):511- 6. https://doi.org/10.1007/s002210050367
16. Schöner G. Recent developments and problems in human movement science and their conceptual implications. *Ecol Psychol.* 1995;7:291– 314. https://doi.org/10.1207/s15326969eco0704_5
17. Reisman DS, Scholz JP, Schoner G. Coordination underlying the control of whole body momentum during sit-to-stand. *Gait Posture*. 2002;15(1):45- 55. https://doi.org/10.1016/S0966-6362(01)00158-8
18. Domkin D, Laczko J, Djupsjobacka M, Jaric S, Latash ML. Joint angle variability in 3D bimanual pointing: uncontrolled manifold analysis. *Exp Brain Res*. 2005;163(1):44- 57. https://doi.org/10.1007/s00221-004-2137-1
19. Martin V, Scholz JP, Schoner G. Redundancy, self-motion, and motor control. *Neural Comput*. 2009;21(5):1371- 414.

https://doi.org/10.1162/neco.2008.01-08-698
20. Alessandro C, Carbajal JP, d'Avella A. A computational analysis of motor synergies by dynamic response decomposition. *Front Comput Neurosci*. 2013;7: 191. https://doi.org/10.3389/fncom.2013.00191
21. Scholz JP, Schoner G. Use of the uncontrolled manifold (UCM) approach to understand motor variability, motor equivalence, and self-motion. *Adv Exp Med Biol*. 2014;826:91- 100. https://doi.org/10.1007/978-1-4939-1338-1_7
22. Yen JT, Auyang AG, Chang YH. Joint-level kinetic redundancy is exploited to control limb-level forces during human hopping. *Exp Brain Res*. 2009;196(3):439- 51. https://doi.org/10.1007/s00221-009-1868-4
23. Scholz JP, Dwight-Higgin T, Lynch JE, Tseng YW, Martin V, Schoner G. Motor equivalence and self-motion induced by different movement speeds. *Exp Brain Res*. 2011;209(3):319- 32. https://doi.org/10.1007/s00221-011-2541-2
24. Dimitriou M, Franklin DW, Wolpert DM. Task-dependent coordination of rapid bimanual motor responses. *J Neurophysiol*. 2012;107(3):890- 901. https://doi.org/10.1152/jn.00787.2011
25. Newell KM, Vaillancourt DE. Dimensional change in motor learning. *Hum Mov Sci*. 2001;20(4-5):695- 715. https://doi.org/10.1016/S0167-9457(01)00073-2
26. Robins MT, Wheat J, Irwin G, Bartlett R. The effect of shooting distance on movement variability in basketball. *Hum Mov Stud,* 2006;50:217-238.
27. Miller SA. Variability in basketball shooting: practical implications. In: Hong Y, editor. *International Research in Sports Biomechanics,* London: Routledge; 2008. P.27–34.
28. Glazier PS, Davids K. On analysing and interpreting variability in motor output. *J Sci Med Sport*. 2009;12(4):e2-3. https://doi.org/10.1016/j.jsams.2009.03.010
29. Higuchi T, Imanaka K, Hatayama T. Freezing degrees of freedom under stress: kinematic evidence of constrained movement strategies. *Hum Mov Sci*. 2002;21(5-6):831- 46. https://doi.org/10.1016/S0167-9457(02)00174-4
30. Clark JE. On becoming skillful: patterns and constraints. *Res Q Exerc Sport*. 1995;66(3):173- 83. https://doi.org/10.1080/02701367.1995.10608831
31. Smeets JB, Frens MA, Brenner E. Throwing darts: timing is not the limiting factor. Exp Brain Res. 2002;144(2):268- 74. https://doi.org/10.1007/s00221-002-1072-2
32. Yamaguchi H, Kondo T. Throwing darts training support system based on analysis of human motor skill. In: Lee S, Cho H, Yoon K, Lee J, editors. *The Intelligent Autonomous Systems 12*. Springer: 2013. P.469– 478. https://doi.org/10.1007/978-3-642-33932-5_43
33. Soderkvist I, Wedin PA. Determining the movements of the skeleton using well-configured markers. *J Biomech*. 1993;26(12):1473- 7. https://doi.org/10.1016/0021-9290(93)90098-Y
34. Suzuki M, Yamazaki Y, Mizuno N, Matsunami K. Trajectory formation of the center-of-mass of the arm during reaching movements. *Neuroscience*. 1997;76(2):597- 610. https://doi.org/10.1016/S0306-4522(96)00364-8
35. Scholz JP, Reisman D, Schoner G. Effects of varying task constraints on solutions to joint coordination in a sit-to-stand task. *Exp Brain Res*. 2001;141(4):485- 500. https://doi.org/10.1007/s002210100878
36. Soechting JF, Flanders M. Errors in pointing are due to approximations in sensorimotor transformations. *J Neurophysiol*. 1989;62(2):595- 608. https://doi.org/10.1152/jn.1989.62.2.595
37. Nakagawa J, An Q, Ishikawa Y, Oka H, Takakusaki K, Yamakawa H, et al. Analysis of Human Motor Skill in Dart Throwing Motion at Different Distance. *JCMSI*. 2015;8(1):79– 85. https://doi.org/10.9746/jcmsi.8.79
38. d'Avella A, Lacquaniti F. Control of reaching movements by muscle synergy combinations. *Front Comput Neurosci*. 2013;7: 42. https://doi.org/10.3389/fncom.2013.00042

Information about the authors:

HosseiniZarch S.H.; PhD of Motor Behavior; http://orcid.org/0000-0001-5497-4036; hhzarch@gmail.com; Department of Physical Education and Sport Sciences, Kharazmi University;; No.43.South Mofatteh Ave., 14911, Tehran, Iran.

Arsham S.; (Corresponding author); Assistant Professor of Motor Behavior; http://orcid.org/0000-0003-4424-1650; saeedarsham@yahoo.com; saeedarsham@khu.ac.ir; Faculty of Physical Education and Sports Sciences, Kharazmi University;; No.43.South Mofatteh Ave., 14911, Tehran, Iran.

Tabatabaei Ghomshe S.F.; Associate Professor of Biomedical Engineering; http://orcid.org/0000-0002-6612-0553; Tabatabai@aut.ac.ir; Department of Ergonomics, University of Social Welfare and Rehabilitation Sciences; Kodakyar Ave., Daneshjo Blvd., Evin Tehran 19857-13834. Iran.

Honarvar M.H.; Assistant Professor of Mechanical Engineering; http://orcid.org/0000-0002-4464-7194; hadihonarvar@yazd.ac.ir; Faculty of Engineering, Yazd University; University Blvd., Safayieh, 8915818411 Yazd, Iran.

Cite this article as:
HosseiniZarch SH, Arsham S, Tabatabaei Ghomshe SF, Honarvar MH. Identifying control structure of multi-joint coordination in dart throwing: the effect of distance constraint. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):267-281.
https://doi.org/10.15561/18189172.2019.0601

Received: 23.07.2019
Accepted: 25.08.2019; Published: 30.09.2019

Comparative study of anthropometric measurement and body composition between soccer players from different competitive levels, elite and sub-elite

Masanovic B.[1ABCDE], Milosevic Z.[2ABCD], Bjelica D.[1ABDE]
[1]*Faculty for Sport and Physical Education, University of Montenegro, Montenegro*
[2]*Faculty of Sport and Physical Education, University of Novi Sad, Serbia*

Authors' contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds collection.

Abstract

Purpose: The purpose of this study was to describe anthropometric characteristics and body composition of soccer players from different competitive levels, elite and sub-elite as well as to make comparison between them.

Material: Seventy-seven subjects were enrolled in this study, divided into three groups: twenty-six elite soccer players, twenty sub-elite soccer players and thirty-one healthy sedentary subjects. All subjects were assessed for anthropometric measurements required for the calculation of body composition variables using standardized procedures which were recommended by previous studies. Data was analyzed by using SPSS and the descriptive statistics were expressed as a mean (SD) for each variable, while the ANOVA and the LSD Post Hoc tests were carried out to discover effects of each type of sport.

Results: The results showed that a significant difference was found in weight, body mass index, bone content and body fat, while a significant difference was not found in two remaining variables, height and muscle mass.

Conclusions: Therefore, these findings may give coaches from the region better working knowledge and thus provide knowledges for soccer experts which will help them to select talented players as best as possible.

Keywords: morphological characteristics, body composition, male athletes, senior.

Introduction

Based on a survey conducted by the Fédération Internationale de Football Association we find that 269.610 million men and women are active in playing football [1]. This incredible number represents 4.13% of the world's population, and 10% of them are women. Of the number mentioned above, 226.265 million are unregistered occasional players, and 38.287 million are registered players. The registered players include 113.000 professional soccer players, 15.481 million amateur league players aged 18 and older, 21.548 million young players up to 18 years old, 1.112 million futsal players and 33 000 beach soccer players. From the same sources, we find that there are 301.000 registered clubs and 1.752 million teams in the world. Also, that the increase of football consumers between 2000 and 2006 is clearly visible. Number of registered players increased by 23% in this period and the number of occasional unregistered players by 7%. Hence, with 242 million men and women active in playing football in 2000, the total figure reached the number of 265 million men and women active in playing football in 2006. So many interested people obligate scientists from around the world to seriously deal with this field of sport and to help young people who want to compete to find their place in such a complex structure of the organization.

It is obvious that the desires and motives that encourage each individual to deal with this sport are not the same. Some have the desire to be actively engaged in soccer and choose this sport as a profession, while others want to play soccer recreationally and through it satisfy some completely other desires, such as the maintenance of psychophysical abilities at the optimum level. For such a form of playing free choice, and proper medical control are characteristic [2-5]. Playing soccer at an amateur league level is reflected in the massive number of recipients and the widespread distribution in each environment [6]. On the contrary, elite soccer can be defined as an activity aimed at achieving the greatest accomplishments in sport, and we can mark the sport result as the basic measuring unit of success [7, 8].

The focus towards the greatest sport results and professional soccer is very dependent on the timely selection of players [9]. In elite soccer, experts are constantly looking for the most effective formula for recognizing and developing talented young players, because their goal is to find those players who are, based on their attributes, the most similar to top-level and already proven players [10].

In order to achieve this goal, they have to be focused on the long-term development of soccer players, because different factors may predispose individuals towards a successful career, and identifying characteristics that distinguish performers can be very difficult [11, 12].

Some answers to this issue can be detect by comparing the anthropometric characteristics and the body composition of players of elite ranks of competition and the lower-ranked players [13-15]. Comparisons between players exposed to systematic training with already highly selected players can help to establish the distinguishing features of expertise and to identify the factors that

doi:10.15561/18189172.2019.0602

determine a player's potential to progress to higher levels of play [16, 17].

The purpose of this study is to describe the anthropometric characteristics and body composition of the soccer player of different levels of competition, to examine the differences between two competitive levels, elite and sub-elite, and thus provide soccer experts with knowledges which will help them to select talented players as best as possible.

Material and Methods

Participants: Seventy-seven male athletes were enrolled in this study. They were divided into three groups: twenty-six elite soccer players (23.23±3.35 yrs.) from the Serbian Premier League, twenty sub-elite players (23.60±4.74 yrs.) from the Fifth Serbian League and thirty-two healthy sedentary subjects from the same country (24.94±3.10 yrs.). Testing was conducted in the winter preparation period.

Procedure: All subjects were clinically healthy and had no recent history of infectious disease, asthma or cardio-respiratory disorders. All of them gave their written consent and the local ethics committee approved the protocol of the study. All subjects were assessed for the twenty anthropometric measures required for the calculation of body composition variables, using the standardized procedure recommended by the International Biological Program (IBP) [18] standards respecting the basic rules and principles related to the parameter choice, standard conditions and measurement techniques, as well as the standard measuring instruments adjusted before measurement was carried out. Height and weight were measured in the laboratory with the subject dressed in light clothing. Height was measured to the nearest 0.1 cm using a fixed stadiometer, and weight was measured to the nearest 0.1 kg with a standard scale utilizing a portable balance. Skinfolds (mm) were measured at six sites: triceps skinfold thickness, forearm skinfold thickness, thigh skinfold thickness, calf skinfold thickness, chest skinfold thickness and abdominal skinfold thickness (using a skinfold caliper). The circumferences (cm) were measured at eight sites: minimum and maximum circumference of the upper arm, minimum and maximum circumference of the forearm, minimum and maximum circumference of the upper leg, minimum and maximum circumference of the lower leg (using a anthropometric tape). At last the following diameters were measured to the nearest 0.1 cm: elbow diameter, wrist diameter, diameter of the knee, diameter of the ankle (using a small siding caliper). To reduce measurement variation, the same investigator examined all of the subjects. Body mass index (BMI) was calculated as body mass in kilograms divided by height in meters squared (kg/m^2). The values of bone, muscular, and fat contents of body composition were acquired by distributing all the measured variables in formulas by Mateigka [19].

Statistical analysis: The data obtained in the research was processed using the application statistics program SPSS 20.0, adjusted for use on personal computers. The descriptive statistics were expressed as a mean (SD) for each variable. Analysis of the variance (ANOVA) and the LSD Post Hoc test were carried out to detect the effects for each level of competition (elite or sub-elite) on each variable: body height, body weight, body mass index (BMI), and muscle, bone and fat content of the body, as well as to control it by sedentary subjects. The significance was set at an alpha level of 0.05.

Results

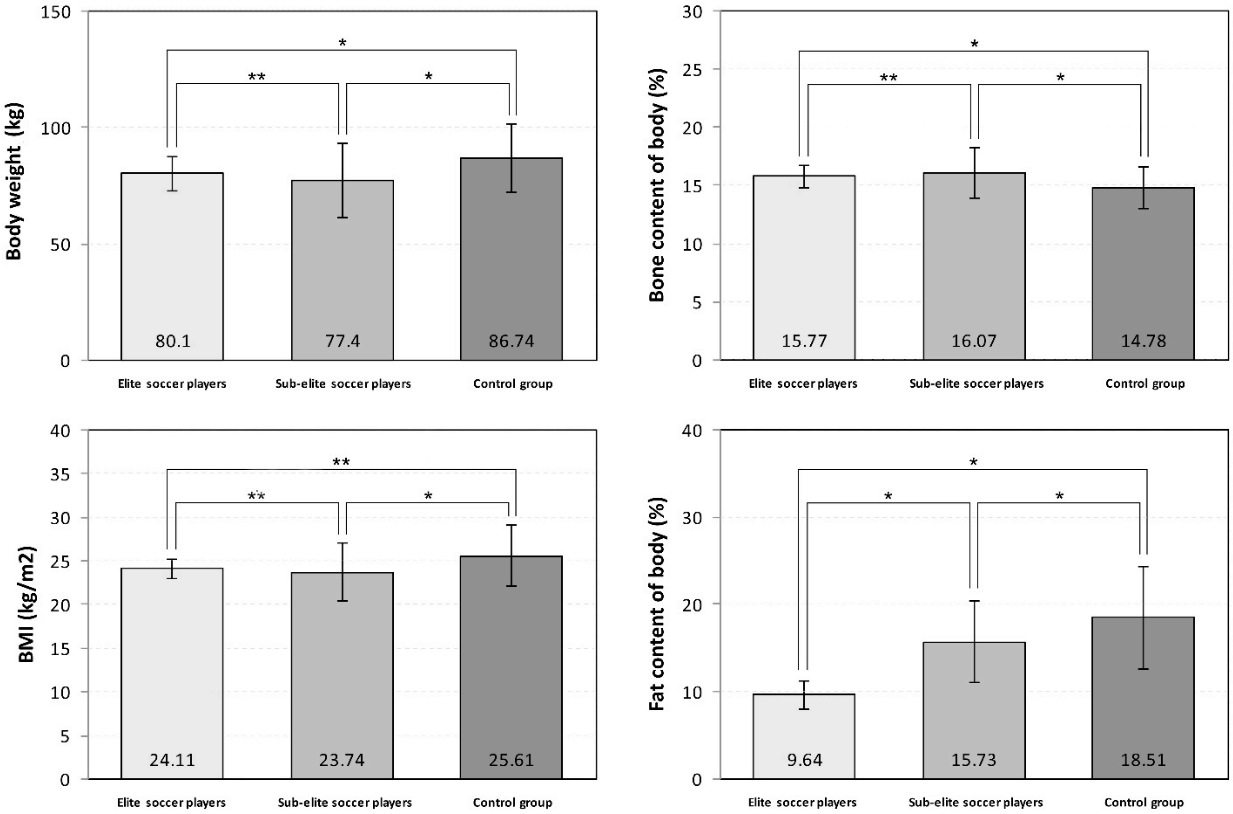
Anthropometric characteristics of subjects are shown in Table 1. There were significant differences in four out of six variables among the groups. Hence, a significant difference was found for weight (F= 3.56), body mass index (F= 3.23), bone content (F=4.27) and body fat (F=27.72). There is no significant difference in the remaining two variables: height (F= 1.78) and muscle mass (F=2.16).

Significant differences of anthropometric characteristics among particular sports are shown in Figure 1. The LSD Post Hoc test indicated that subjects from the control group were heavier and have higher body mass index than elite soccer players and sub-elite soccer players who have the lowest value of both mentioned parameters. When it comes to bone content, sub-elite soccer players have highest percentage, while subjects from the control group have lowest percentage of bone content. Lastly, elite soccer players had the lowest percentage of body fat, while subjects from the control group had the highest percentage body fat. It was not found any significant difference for the muscle mass, but

Table 1. Descriptive data and ANOVA of male athletes enrolled in the study (n=71)

Variables	Elite Soccer (n=26)	Sub-Elite Soccer (n=20)	Control (n=31)	ANOVA
		Mean ± Standard Deviation		
Height (cm)	182.11±6.73	179.77±7.51	183.72±7.60	0.175^
Weight (kg)	80.10±7.13	77.40±16.04	86.74±14.68	0.033*
BMI (kg/m^2)	24.11±1.14	23.74±3.30	25.61±3.49	0.045*
Muscle mass (%)	49.90±2.78	49.66±3.18	48.32±3.27	0.123^
Bone content (%)	15.77±0.92	16.07±2.20	14.78±1.78	0.018*
Body fat (%)	9.64±1.60	15.73±4.67	18.51±5.89	0.000*

Note: N - number of subjects; BMI - body mass index; ^ - non-significant; * - significant difference between groups.



Legend: * - significance; **- non-significance.

Figure 1. LSD Post Hoc test for the different parameters among the subjects

it was noticed that elite soccer players had the highest muscle mass, while subjects from the control group had the lowest values.

Discussion

Some previous studies suggest that there has been a tendency to recruit taller and heavier soccer players [20]. The absence of differences between soccer players and subjects from the control group in this study raises doubts that the selection process has been carried out correctly, especially since even elite soccer players are shorter than subjects from the control group. Nevertheless, it has to be considered that the average body height of all participants in the FIFA 2018 World Soccer Cup that took place in Russia 2018 was 182.41 centimeters, while the average body height of the national team of France, who won the first place on championship, was 183.3. On the other hand, Luka Modric and Kylian Mbappe, the best player and the best young player of the FIFA 2018 World Cup in Russia 2018, were 172 and 178 centimeters tall, while the most valuable French and Belgian players, Antoine Griezmann and Eden Hazard, were 175 and 173 centimeters tall. Mentioned official statistical data proved that elite soccer players involved in this study were tall enough and did not lag behind the top World players, and that the selection of players was well done, which is not a surprise given that the high percentage of very high subjects is a characteristic of people from this area [21-23]. Likewise, the tendency to recruit taller soccer players is not unsworn in the scientific literature yet [24-26]. When it comes to sub-elite players, they are somewhat lower than the other two remaining group of respondents, but this is consistent with previous literature that points out that sub-elite players have a lower average height than the elite [13, 27].

However, we found that subjects from the control group have the highest body mass and highest values of body mass index. The values of both of these variables are slightly higher than in the case of elite soccer players, and significantly higher than sub-elite soccer players, which corresponds with previous studies [14, 28]. Body mass and BMI subjects from the general population are higher because their physical activity is far lower than the activity of soccer players from both groups. On the other hand, body weight and BMI elite players are higher than when it comes to sub-elite players, because the body of elite players must be stronger due to higher demands of their ranking [6].

Surprisingly, we did not find any significant differences among the groups regarding muscle mass, as it is widely known that increasing lean body mass is important to improve strength and power, relevant to sport performance [29]. However, it is not a worry factor because, fortunately, the muscle mass of soccer players from this study corresponds to the values obtained from previous studies [30], and high values of muscle mass of sub-elite soccer players and subjects from control group point out the high quality of their training, i.e. the correct diet.

On the contrary, the percentage of bone content of elite soccer players is of the highest values, slightly higher than the percentage of bone content of sub-elite soccer players, and significantly higher than those of subjects from the control group, which supports the previous knowledges of positive impact of physical activity on bone mass [31, 32].

Lastly, a low percentage of body fat of elite soccer players from this study, which was significantly lower than the percentage of body fat of sub-elite soccer players and subjects from the control group, showed that elite players have a high level of physical performance. Also, sub-elite soccer players had a significantly lower percentage of body fat than subjects from the control group, which is also expected, because in many previous studies soccer has been recognized as an aerobic sport [33, 34] in which, as it is known, excessive fat mass compromises physical performance [35, 36]. Certainly, it is very important to remember that the National Strength and Conditioning Association indicates that body fat percentages should not be lowered below 7 percent, because soccer players need a certain body fat percentage to perform well enough and achieve their full playing potential.

The importance of body composition in sport performance is a primary concern in creating elite soccer players profiles as well as conditioning programs throughout a season at all levels of competitions [28]. Also, describing anthropometric characteristics and body composition of soccer players and detecting possible differences in relation to competition levels may give coaches a better working knowledge of the studied groups, and can allow them to identify the factors that determine a player's potential to progress to higher levels of play.

Conclusion

The results of this study suggest that soccer players from both competitive levels had a slightly higher percentage of muscle mass and significantly lower percentage of body fat in comparison to the control group, while that elite soccer players had slightly higher percentage of muscle mass and significantly lower percentage of body fat in comparison to the sub-elite soccer players. This study also suggests that soccer players from both competitive levels had significantly increased bone content in comparison to the control group. The part attributed to the body height is the main cause of the selection process, and lastly, the part attributed to body weight and BMI could be the main cause consequence of nutritional habits.

The limitation of this study is that testing has been carried out in the middle of the competition season, and the body composition may change during the season [37]. Accordingly, the next testing should be planned at the beginning and at the end of the season, because in that way they would have an accurate insight into the changes during the macrocycle. In this way more representative data will certainly be provided, but this does not diminish the contribution of this preliminary study, because it also contains data that can help football experts to select talented players as best as possible.

Conflicts of interest

The authors declare no conflict of interest.

References

1. *Big Count 2006. Statistical Summary Report by Gender/Category/Region.* [Internet]. 2007 [cited 2007, May 31]. Available from: https://www.fifa.com/media/news/y=2007/m=5/news=fifa-big-count-2006-270-million-people-active-football-529882.html
2. Gardašević J, Georgiev G, Bjelica D. Qualitative changes of basic motor abilities after completing a six-week training programme. *Acta Kinesiologica.* 2012; 6(1):70-74.
3. Gjonbalaj M, Georgiev G, Bjelica D. Differences in Anthropometric Characteristics, Somatotype Components, and Functional Abilities Among Young Elite Kosovo Soccer Players Based on Team Position. *International Journal of Morphology*. 2018; 36(1):41-47. https://doi.org/10.4067/S0717-95022018000100041
4. Aslan A, Salci Y, Guvenc A. The effects of weekly recreational soccer intervention on the physical fitness level of sedentary young men. *Montenegrin Journal of Sports Science and Medicine.* 2019; 8(1):51-59. https://doi.org/10.26773/mjssm.190308
5. Akelaitis A, Malinauskas R. The expression of emotional skills among individual and team sports male athletes. *Pedagogics, psychology, medical-biological problems of physical training and sports*. 2018;22(2):62-67. https://doi.org/10.15561/18189172.2018.0201
6. Gissis J, Papadopoulos C, Kalapotharakos VI, Sotiropoulos A, Komsis G, Manolopoulos E. Strength and Speed Characteristics of Elite, Subelite, and Recreational Young Soccer Players. *Research in Sports Medicine.* 2015; 14(3):205-214. https://doi.org/10.1080/15438620600854769
7. Gardasevic J, Bjelica D, Vasiljevic I. Morphological Characteristics and Body Composition of Elite Soccer Players in Montenegro. *International Journal of Morphology.* 2019; 37(1):284-288. https://dx.doi.org/10.4067/S0717-95022019000100284
8. Herdy C, Costa PB, Simão R, Selfe J. Physiological profile of Brazilian elite soccer players: Comparison between U-17, U-20 and professionals. *Journal of Anthropology of Sport and Physical Education.* 2018; 2(3):43-47. https://doi.org/10.26773/jaspe.180708
9. Gjonbalaj M, Georgiev G, Bjelica D. Differences in Anthropometric Characteristics, Somatotype Components, and Functional Abilities Among Young Elite Kosovo Soccer Players Based on Team Position. International Journal of Morphology. 2018;36(1):41-47. ttps://doi.org/10.4067/s0717-95022018000100041
10. Popovic S, Bjelica D, Jaksic D, Hadzic R. Comparative Study of Anthropometric Measurement and Body Composition between Elite Soccer and Volleyball Players. *International Journal of Morphology*. 2014; 32(1):267-274. https://doi.org/10.4067/S0717-95022014000100044
11. Nikolaidis PT, Vassilios Karydis N. Physique and body composition in soccer players across adolescence. *Asian Journal of Sports Medicine.* 2011; 2(2):75-82. https://doi.org/10.5812/asjsm.34782
12. Björkman I, Ehrnrooth M, Mäkelä K, Smale A, Sumelius J. Talent or Not? Employee Reactions to Talent Identification. *Houman Resource Management.* 2013; 52(2):195-214.

https://doi.org/10.1002/hrm.21525
13. Paillard T, Noé F, Rivière T, Marion V, Montoya R, Dupui P. Postural performance and strategy in the unipedal stance of soccer players at different levels of competition. *Journal of athletic training*. 2006; 41(2):172-176.
14. Butler RJ, Southers C, Gorman PP, Kiesel KB, Plisky FJ. Differences in Soccer Players' Dynamic Balance Across Levels of Competition. *Journal of Athletic Training*. 2012; 47(6):616-620. https://doi.org/10.4085/1062-6050-47.5.14
15. Mohammed Z. Body composition versus body fat percentage as predictors of posture/balance control mobility and stability among football players under 21 years. *Physical Education of Students*. 2017;21(2):96-102. https://doi.org/10.15561/20755279.2017.0208
16. Gravina L, Gil SM, Ruiz F, Zubero J, Gil J, Irazusta J. Anthropometric and Physiological Differences Between First Team and Reserve Soccer Players Aged 10-14 Years at the Beginning and End of the Season. *Journal of Strength and Conditioning*. 2008; 22(4):1308-1314. https://doi.org/10.1519/JSC.0b013e31816a5c8e
17. Akbari H, Sahebozamani M, Daneshjoo A, Amiri-Khorasani M. Effect of the FIFA 11+ programme on vertical jump performance in elite male youth soccer players. *Montenegrin Journal of Sports Science and Medicine*. 2018; 7(2):17-22. https://doi.org/10.26773/mjssm.180903
18. Mišigoj-Duraković M, Matković B, Medved R. *Morfološka antropometrija u športu* [Morphological anthropometry in sports]. Zagreb, Croatia: Fakultet za fizičku kulturu; 1995.
19. Matiegka J. The testing of physical efficiency. *American Journal of Physical Anthropology*. 1921; 4:223-230. https://doi.org/10.1002/ajpa.1330040302
20. Gil SM, Gil J, Ruiz F, Irazusta A, Irazusta J. Anthropometrical Characteristics and Somatotype of Junior Soccer Players and Their Comparison with the General Population. *Biology of Sport*. 2010; 27(1):17-24. https://doi.org/10.5604/20831862.906762
21. Bjelica D, Popovic S, Kezunovic M, Petkovic J, Jurak G, Grasgruber P. Body Height and Its Estimation Utilizing Arm Span Measurements in Montenegrin Adults. *Anthropological Notebook*. 2012; 18(2):69-83.
22. Popovic S, Bjelica D, Molnar S, Jaksic D, Akpinar S. Body Height and Its Estimation Utilizing Arm Span Measurements in Serbian Adults. *International Journal of Morphology*. 2013; 31(1):271-279. https://doi.org/10.4067/S0717-95022013000100043
23. Masanovic B. Standing height and its estimation utilizing arm spam and foot length measurements in dinaric alps population: a systematic review. *Sport Mont*. 2018; 16(2):101-106. https://doi.org/10.26773/smj.180619
24. Almagia A, Araneda A, Sánchez J, Sánchez P, Zúñiga M, Plaza P. Somatotype and Body Composition of the Male University Soccer Team at Pontificia Universidad Católica de Valparaíso, Champions 2012-2013. *International Journal of Morphology*. 2015; 33(3):1165-1170. https://doi.org/10.4067/S0717-95022015000300057
25. Masanovic B, Corluka M, Milosevic Z. Comparative Study of Anthropometric Measurement and Body Composition of Junior Soccer and Handball Players from the Serbian National League. *Kinesiologia Slovenica*. 2018; 24(3):37-46. https://doi.org/10.4067/S0717-95022019000200612
26. Krespi M, Sporis G, Popovic S. Exponential versus linear tapering in junior elite soccer players: effects on physical match performance according to playing positions. *Montenegrin Journal of Sports Science and Medicine*. 2019; 8(1):17-22. https://doi.org/10.26773/mjssm.190303
27. Sæther SA. Characteristics of professional and non-professional football players - an eight-year follow-up of three age cohorts. *Montenegrin Journal of Sports Science and Medicine*. 2017; 6(2):13-18. https://doi.org/10.26773/mjssm.2017.09.002
28. Popovic S, Akpinar S, Jaksic D, Matic R, Bjelica D. Comparative Study of Anthropometric Measurement and Body Composition between Elite Soccer and Basketball Players. *International Journal of Morphology*. 2013; 31(2):461-467. https://doi.org/10.4067/S0717-95022013000200016
29. Vila Suárez MH, Ferragut C, Alcaraz PE, Rodríguez Suárez N, Cruz Martínez M. Anthropometric and strength characteristics in junior handball players by playing positions. *Archivos de Medicina del Deporte*. 2008; 125(3):167-177.
30. Jeukendrup AE, Gleeson M. *Sport Nutrition: An Introduction to Energy Production and Performance*. Champaign, Human Kinetics, 2009.
31. Darwin C. *On the Origin of Species, 1859*. London: Routledge, 2013. https://doi.org/10.4324/9780203509104
32. Tobin WJ. The internal architecture of the femur and its clinical significance: the upper end. *The Journal of Bone and Joint Surgery*. 1955; 37(2):434-434. https://doi.org/10.2106/00004623-195537020-00033
33. Santos-Silva PR, Fonseca AJ, De Castro AW, Greve JMD, Hernandez AJ. Reproducibility of maximum aerobic power (VO2max) among soccer players using a modified heck protocol. *Clinics*. 2007; 62(4):391-396. https://doi.org/10.1590/S1807-59322007000400004
34. Polevoy G. Development of the ability to differentiate the parameters of football players' movements taking into account their typology. *International Journal of Applied Exercise Physiology*. 2018; 7(2):26-31. https://doi.org/10.22631/ijaep.v7i2.268
35. Ramos-Campo DJ, Martínez-Sánchez F, Esteban-García P, Rubio-Arias JA, Bores CA, Clemente-Suarez VJ, Jiménez-Díaz JF. Body Composition Features in Different Playing Position of Professional Team Indoor Players: Basketball, Handball and Futsal. *International Journal of Morphology*. 2014; 32(4):1316-1324. https://doi.org/10.4067/S0717-95022014000400032
36. Arifi F, Bjelica D, Masanovic B. Differences in anthropometric characteristics among junior soccer and handball players. *Sport Mont*. 2019; 17(1):45-49. https://doi.org/10.26773/smj.190208
37. Nepocatych S, Balilionis G, O'Neal EK. Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine*. 2017; 6(2):57-65. https://doi.org/10.26773/mjssm.2017.09.008

Information about the authors:

Masanovic B.; (Corresponding author); http://orcid.org/0000-0002-4939-4982; bojanma@ucg.ac.me; University of Montenegro; Cetinjski put 2, 81000, Podgorica, Montenegro.

Milosevic Z.; http://orcid.org/0000-0001-7408-2545; zoranaisns29@mail.com; University of Novi Sad; Lovcenska 16, 21000, Novi Sad, Serbia.

Bjelica D.; http://orcid.org/0000-0001-5272-528X; dbjelica@ucg.ac.me; University of Montenegro; Cetinjski put 2, 81000, Niksic, Montenegro.

Cite this article as:
Masanovic B, Milosevic Z, Bjelica D. Comparative study of anthropometric measurement and body composition between soccer players from different competitive levels, elite and sub-elite. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):282-287.
https://doi.org/10.15561/18189172.2019.0602

Received: 10.08.2019
Accepted: 20.09.2019; Published: 30.09.2019

The effects of tow protocol cold water immersion on the post match recovery and physical performance in well-trained handball players

Mokhtar M.[1ABDE], Adel B.[1BCDE], Wahib B.[2ABC], Hocine A.[3BC], Othman B.[1CD], Mohamed S.[2CDE]

[1]*Laboratory of Optimizing Research Programmes on Physical and Sports Activities, Institute of Physical Education and Sport, University of Mostaganem, Algeria*

[2]*Laboratory of Applied Sciences to Human Movement Institute of Physical Education and Sport, University of Mostaganem, Algeria*

[3]*Institute of Physical Education and Sport, University of Oran, Mostaganem, Algeria*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: The purpose of this study is to compare two cold water immersion (CWI) protocols, continuous and fractionated, to optimize the recovery of Handball players after on recovery from exercise resulting in exercise-induced muscle damage.

Material: Ten male Handball players (age: 15 ± 1.4 years, mass index: 67.2 ± 5.1 kg, height: 176.6 ± 7.30) voluntarily participated in the study. After three 90-minute training sessions (average heart rate 160 ± 15.81, 156 ± 5.53 and 156 ± 12.24 bpm) per week, participants were divided into 03 groups. The first experimental group (GE1) in continuous immersion (CWIC) of (12 minutes, 12± 0.4° C), a second experimental group (GE2) in fractional immersion (CWIF) of (4 x 2 min at 12 ± 0.4° C + 1 min out of water) and a control group (GC) in passive recovery. Body mass indices (BMI), countermovement (Countermovement jump) and muscle pain (Intensity of pain in the thighs) were measured.

Results: The results concerning the percentage differences in the variation of the CMJ occurred respectively at 24h ($Z = 12.62$, $p = 0.004$) and 48h ($Z = 16.22$, $p <0.001$) compared to the control group. In addition, the results for muscle volume did not report any significant interaction ($F (5.64) = 3.42$, $p = 0.078$). The results of both protocols showed their effectiveness in reducing pain intensity by 24 and 48 hours after intense training ($F (3.54) = 2.91$, $p = 0.016$, $p2 = 0.24$).

Conclusions: In conclusion, continuous and fractionated cold water immersion is beneficial for neuromuscular recovery 24 hours after intense exercise. The results also demonstrate a rapid recovery of handball players from their physical potential required in high level competitions.

Keywords: cold water, immersion, recovery, handball, physical performance.

Introduction

There is Cold water immersion (CWI) is a popular form of cryotherapy and considered one of the most effective for reducing tissue temperature and sustained cooling after removal [1] and speed up the recovery process [2, 3].

Different approaches to these methods [3, 4], as well as the results [4–7] have shown a beneficial effect of these techniques in recovery. In contrast, other studies have reported no significant effect on recovery [8, 9].

More specifically, experimental studies indicate that CWI generates a series of physiological changes including, the reduction of core body temperature [10, 11], acute inflammation [12], muscle spasms, and pain sensations [13], localized edema [12], as well as symptoms related to delayed onset muscle pain [14–17]

The perception of fatigue and levels of creatine phosphokinase (CPK),, another study to realize by [10], whose aim was to examine the effects of 20-minute (14° C) imersion on neuromuscular function, recommendations were made to suggest that temperature and duration Optimal CWI for performance-based exercise recovery and management of exercise-induced muscle damage are at 10-15° C and 5-15 min [3, 21].

Most of these studies compared CWI under control or passive recovery, using continuous dips [17, 21–23]. On the other hand, CWI has also been used through the fractional method. The results concluded that this form of immersion has no effect on the athlete's recovery and performance [24, 25], In addition, another study [19] reports positive effects on recovery using CWI intermittently.

These contradictory results make necessary the deeper exploration of these approaches to be able to bring objective and weak answers. Moreover, despite the wide dissemination and use of this recovery technique [3], to our humble knowledge [26], only one study has explored the use of this technique in Handball players [7]. The protocol to use was that of the split CWI. The results showed a positive effect on handball recovery. However, no study has explored the effects of the two methods on recovery among university Handball players in team sports.

The advanced physiological mechanisms when using fractional immersions show a pumping effect caused by vasoconstriction and vasodilatation, which occur due to temperature change. This pumping effect stimulates the transport of waste and nutrients into the body [8, 27]. In contrast, continuous immersions are advocated as a result of increased exposure to cold and the effects of vasoconstriction and hydrostatic pressure which together

doi:10.15561/18189172.2019.0603

facilitate processes such as, rapidly decreasing body temperature, and acceleration of processes associated with decreased pain [28].

Hypothesis: This study set out to test the hypothesis that, we assume that the response of the recovery indicators varies significantly depending on the type of CWI recovery protocol.

Purpose: Therefore, the main objective of this study is to compare the effects of two recovery protocols by CWI after a state of intense fatigue in highly-trained university Handball players

Materials and Methods

Participants

The subjects who voluntarily participated in this experiment were Hand Ball players between 14 and 15 years of age (15±1.4 years of age) and a body weight of 67.2 ± 5.1 kg, with a height of 176 ± 3.02 cm. Their sporting experience was (5±2 years) on average. They trained three times a week. Each training session lasts 1 hour and a half. In addition, the entire team regularly participated in one competition once a week, for a total of 12 competitions during the pre-competitive period (Fig. 1). The experimental procedures, the associated risks and benefits were explained to each player through a consent form signed by the parents.

Subjects were homogeneously distributed A balanced design was applied in which subjects in Experimental Group 1 received the abstract (CWI.C), subjects in Experimental Group 2 received the (CWIF) and subjects in the Control Group received the a (GC). This population was passively recovered, as shown in Figure 1, and this study was conducted prior to the competition period. The study was designed in accordance with the recommendations for clinical research in the Declaration of Helsinki [29] . The protocol was reviewed and approved by a committee of experts from the Institute of Physical Education and Sport of the University of Mostaganem (Algeria).

Study Design

Body composition and anthropometric measurements:

The mass index was determined using a model (Tanita BC-1500, Japan 2015) with an accuracy of ± 0.1 kg. The height was measured using a wall stadiometer. The Percentage of fat was calculated using a skin fold caliper, data from 7 sites (chest, medial-axillary subscapular, triceps, suprailiac, abdomen and thigh) [30, 31] were evaluated. All measurements were made with an anthropometric measurement calculation tool [32] . The water temperature was monitored and recorded using a DeltaTrak digital thermometer, model 12207 (Lima, Peru) at 1-minute intervals.

The Performance and Recovery Indicators:

Perceived pain:

The visual analog scale (VAS 0-10) was used to measure the pain perceived by the subjects. In this case, zero (0) indicates no pain and ten (10) indicate extreme pain. To determine the level of pain, subjects were asked to perform the 90-degree chase test and indicate the perceived muscle pain in the thigh. This method has already been used in pain perception after intense exercise [14, 18, 19, 25] .

The circumference and volume of the thigh were measured using an anthropometric tape measure. Circumference was measured at two locations on the leg, under the buttock and above the knee. A marker was used to ensure the reliability of the re-test (before the recovery protocol and at 24 and 48 hours respectively after recovery). These data allow the calculation of thigh volume, which is an indicator of inflammation and muscle damage [10] . The formula updated by [33–36] was used to calculate muscle volume as Follows:

Vol= h/12 x π x [C12 + C22+ (C1) x (C2)]

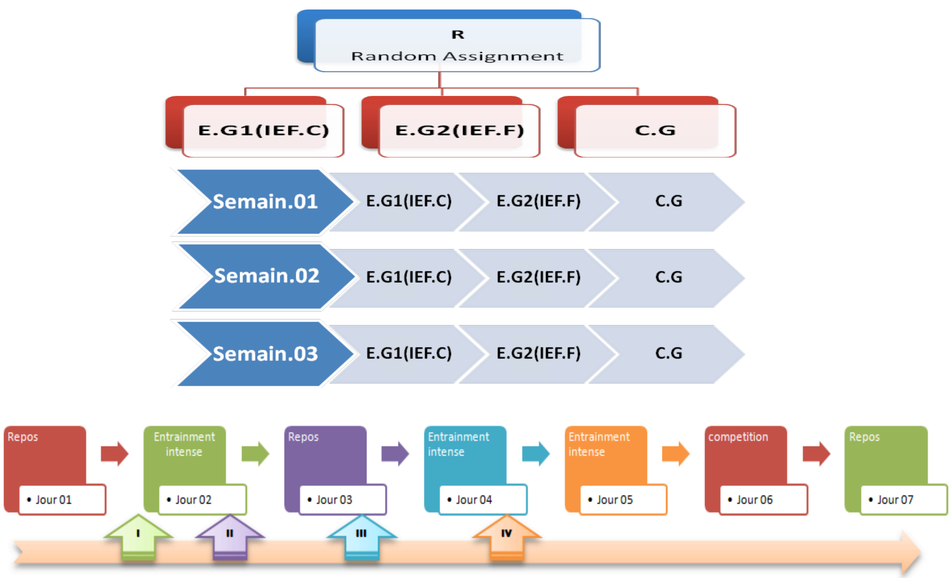


Figure 1. Shows the random assessment of the study

Note: h =high thigh; Π =3, 14; C1=Sub-gluteal circumference; C2= above knee circumference.

The counter-movement jump test (CMJ):

The measurements were made using a force platform. Three tests were performed with a recovery time of 2 minutes, and the best jump was recorded for each measurement episode. The jump countermovement test (CMJ) has an intra-class correlation reliability (CIC=0.98) [37] . All variables were measured before and immediately after the recovery (from 0 hours) and at 24 and 48 hours after cold water immersion.

Statistical Analyses

Descriptive statistics (mean and standard deviation) were calculated for all variables. The normality of the data was assessed using the Shapiro-Wilks test. The results indicated normality for all variables except muscle volume and MJF performance, which were analyzed in terms of percentage change from the previous value. Since the values of these two variables were not normally distributed, another non-parametric statistical analysis was performed, using the Kruskal-Wallis H test. The other variables were analyzed with their own units of measurement. The Levene test was used to analyze the homogeneity of variances. Repeatedly measured ANOVAs were used to compare post-exercise muscle pain at 0, 24 and 48 hours after exercise. Bonferroni post hoc analysis was used.

Results

Table 1 above presents descriptive data for the variables associated with recovery for each of the experimental conditions (CWI C, CWI F, and GC) at different measurement times. Statistically significant differences do not appear for pain perception and counter-jump movement (p<.05); details are presented in (Figure 2).

Figure 2 above shows a significant interaction (F (3.92) = 3.62, p = 3.16, p =.24) with the two immersion protocols (CWI.C CWI.F) and significantly reducing pain perception compared to GC (passive recovery) perceptions in measurements immediately after immersion (CWI.C Vs CG, p<.001) (CWI.F Vs CG, p =.009), at 24 hours (CWI.C Vs CG, p =.021) (CWI.F Vs CG, p =.024) and 48 hours after immersion (CWI.C Vs CG, p=.017) (CWI.F Vs CG, p=.032).

Statistically significant differences were not reported when comparing the reference value with the post-immersion measurements. In addition, statistically significant differences were not reported (p< 0.05) at any of the measurement times when comparing the continuous immersion group with the split immersion group. Change CMY test CMY 0% (CWI.F * 1 inverted values) CWI.C 2 Pre-Post Exec. 24 hours 48 hours of significant difference with respect to the control group (p<0.05), CG: control group.

Figure 3 above shows statistically significant differences in jump ability by analysis using the MJF test at 24 hours (Z= 12.62, p =0.004 when CWI.C; CWI.F comparison and with GC (passive recovery) (CWI.C vs CG, p=.006) (CWI.F vs GC, p=0.029) and 48 hours after training (Z= 16.22, p<0.001), (CWI.C Vs. CG, p<0.001) (CWI.F vs CG, p=0.017). In addition, no statistically significant differences (p<0.05) were reported when comparing the two groups that were continuously immersed with the fractionated group. Concerning muscle volume, the analysis did not show any significant interaction (F (3.54) = 2.42, p = 0.058).

Discussion

The main purpose of conducting this study was to examine the effects of two cold-water immersion protocols: the CWI C protocol (12 min immersion at 12 ± 0.4°C) and the CWI F protocol (4 times x 2 min immersion at 12 ± 0.4°C + 1 min out of water) after intense exercise on recovery. The main finding of this study is that both immersion protocols are effective in reducing signs of fatigue and delaying the onset of muscle pain. The analyses also showed positive effects on the recovery

Table 1. The mean scores of experimental and control groups

		Percevied pain				Muscle think volume				Counter movement jump			
Variables		basline	0H	24H	48	basline (mm):	0H	24H	48	basline (cm)	0H	24H	48
CWI.C	mean	4.32	2.31	2.52	2.26	4726.03	4663.6	4520.9	4566.9	44.2	43.61	43.03	43.94
	SD	1.63	1.17	1.61	1.2	850.2	843.8	840.5	983.5	5.6	4.89	4.8	5.06
CWI.F	mean	4.86	3.24	2.73	2.55	4735.8	4662.9	4782.1	4703.9	44.7	43.9	43.56	44.64
	SD	1.52	1.56	1.48	1.06	1180.5	1213.4	1122.8	1248.1	4.63	4.94	4.06	4.97
G.C	mean	4.63	5.81	5.02	4.53	5065.9	4934	4894.3	4886	46.76	46.93	45.6	43.3
	SD	1.67	1.59	1.54	0.83	1084.6	1184.2	1102.9	1129.5	7.6	6.95	7.2	7.49

Notes: G.E 1 (CWI.C): Experimental group with the Continuous Cold Water Immersion Protocol. G.E 2 (CWI.F): Experimental group with the Fractionated Cold Water Immersion Protocol. G C: Group control.

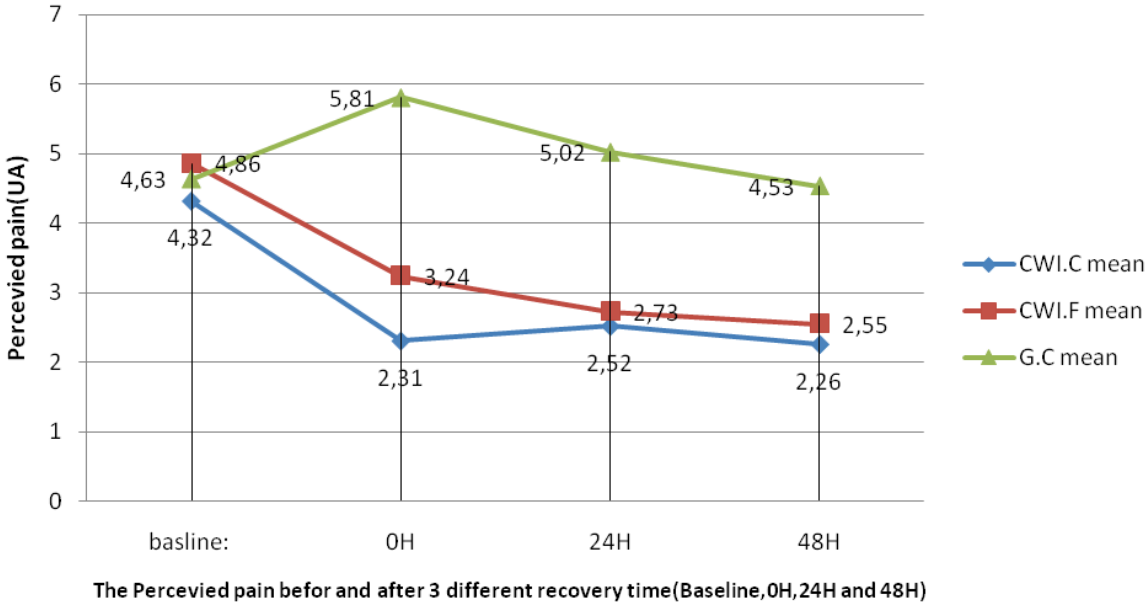


Figure 2. Shows the perception of muscle pain (UA) and its tendency between the 3 groups.

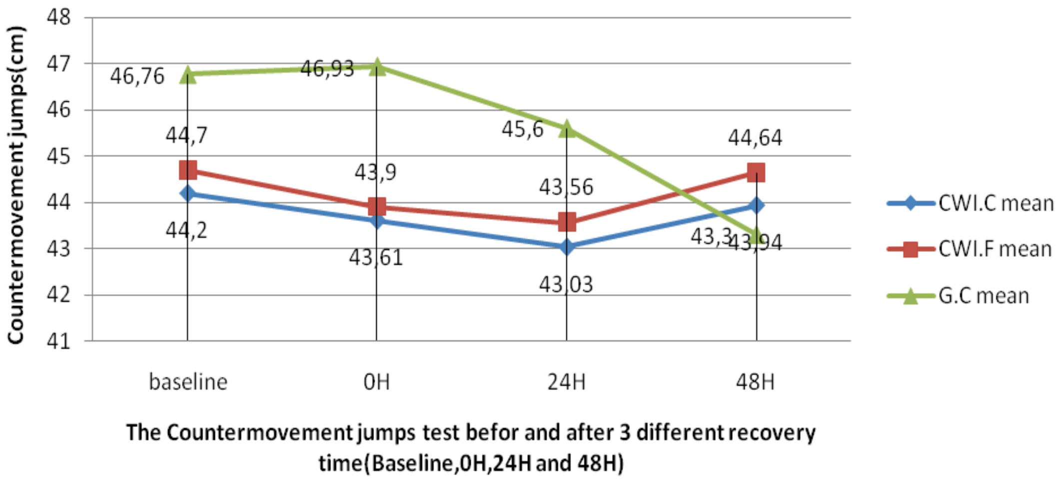


Figure 3. Shows the counter movement jump between the 3 groups CMJ (cm)

of jump capacity measured using the CMJ jump test.

In the case of the study of Simmons [38] , continuous immersion in cold water as part of the 12-minute protocol at 12 ± 0.4°, the latter proved effective in reducing muscle pain immediately after immersion and at 24 and 48 hours after intense exercise. These results are not consistent with the work of Glasgow and stevens [23, 39] but with those reported by Delextrat, Rowsell and Stanley [16, 17, 40] which indicate that cold water reduces the functional and physiological signs associated with muscle pain [41] and confirm that the use of this protocol for CMJ is effective. These results further reinforce protocols with temperatures ranging from 11°C to 15°C, with an immersion time of 10 to 15 minutes that have a positive effect [41] and that MJF techniques appear to be more effective in accelerating performance restoration in different sports by using immersions 5 to 15 minutes at a water temperature of 5-20°C [42] .

In addition, in fractional dives under the 4 x 2 min immersion protocol with a water temperature of 12 ± 0.4°C + 1 min above water at room temperature, the results obtained disagree with those reported by [43] When used, the 3 x 1 min protocol of immersion at 5 ± 1°C, with 1 min out of water, does not report positive effects on DOMS on a comparison of the experimental group with the control group.

Our results are consistent with those reported by Ascensaoand al [19] who used a 5 min x 1 protocol (10 ± 0.5°C + 1 min out of water) at room temperature and reported positive effects of intermittent immersion. These concordances with research results were reported by António Ascensão & Magalhäes [44] who found significant differences both immediately after the immersion protocol and 24 hours after training compared to the control group.

Similarly, Sánchez-Ureña [45] reported significant differences at 24 hours after training between the fractionated immersion group and the control group, using the 2 x 5-minute immersion protocol with water temperature at 10°C and 2.5 minutes out of water at 21°C ± 0.5. This study is the first to report these differences both immediately at 24 and 48 hours after exercise, indicating that the protocol used was characterized by the reversal of the previous protocol.

These physiological results demonstrate that the physiological and functional symptoms associated with Post-Effort Muscle Pain (EPMP) associated with the reduction of acute inflammation [12] , as well as the presence of symptoms in the muscle and the effect of hydrostatic [13, 14] pressure [6] have accelerated recovery. Another mechanism could be related to cold exposure that has shown the potential for activation of the transient 8-melastatin receptor [27, 47] which is related to pain and temperature sensation [48, 49] . Once activated, TRPM8 has an analgesic effect given by the action of the interphas neurons the inhibitory interphase [48, 50] and which improves the perception of DMPE and increases the feeling of recovery [28] .

It is also important to note that exposure to cold causes changes in the neurotransmitters of dopamine and serotonin, which are responsible for regulating mood, sleep, emotions, motivation, pain perception and fatigue. Cold water immersion may help to reduce central nervous system fatigue [28] and suggests that an increase in serotonin/dopamine ratio is associated with fatigue and the rapid onset of fatigue, while a low serotonin/dopamine ratio promotes better performance through maintenance and physiological activation.

In addition, the jump capacity measured by MJF through the two immersion protocols was found to be more effective than passive recovery. This result is consistent with the studies of Mokrani and Stanley & Peake [17, 51] . Indeed, using a continuous immersion protocol, differences were also observed between this group and the control group in terms of effectiveness using the Squat Jump test 48 hours and 72 hours after exercise but not at 24 hours after exercise the exercise between the two groups.

As with cold water immersion, Ascensão [44] used a five-minute protocol after the end of the competition to 2 split dives of the lower limbs (to the iliac crest) in a cold water bath (11°C), separated by 2 min in ambient air (sitting, ambient temperature 20°C) resulted in statistically significant differences 24 hours after the CMJ test immersion. These results are in line with the conclusions of our study.

In addition, the results for thigh volume coincide with those reported by Zagatto et al [52] who also observed that continuous immersion did not significantly decrease edema evaluated at 24, 48 and 72 hours after training. Similar conclusions have been reported by Wilcock & Hing [53] showing that the use of a continuous immersion protocol did not lead to a significant decrease in muscle edema in the immediate posterior measurement. Wilcock [53] also indicated that the thigh circumference (edema) which is an indicator varies less throughout cold water training in the continuous immersion and control groups. The results are identical to the results of this study. One possible explanation is that the load to which the players were exposed did not cause sufficient muscle damage to generate oedema. The results obtained in this study allow sport professionals, such as coaches and trainers [54] to choose the best protocol for their athletes according to their preference, given the effectiveness of both protocols.

Conclusion

In the field of sports training and more particularly in the field of active recovery, more work is needed to compare different cold water immersion protocols, including the measurement of biochemical variables such as creatine phosphokinase (CPK) and lactate dehydrogenase (LDH) physiological myographic surfactants as well as other variables such as reaction time [55] , contraction and muscle relaxation time. In addition, it is necessary to test different split immersion protocols that take into account immersion times, in-water and out-water relationships and temperature differences to optimize the most appropriate protocol for the type of sport.

Acknowledgments

The authors would like to thank the Handball players who participated in the study for their time and patient. We also want to thank the University coach and his staff and also ADDA abdeidaim for valuable contributions and careful proofreading. Thank you for your inspiration and for being a great friend and colleague.

Disclosure statement of funding: Algerian Olympic Sports Centre and Institute of physical education and sports Sciences.

Conflict of interests

The authors declare that there is no conflict of interests.

References

1. Vieira A, Siqueira AF, Ferreira-Junior JB, do Carmo J, Durigan JLQ, Blazevich A, et al. The Effect of Water Temperature during Cold-Water Immersion on Recovery from Exercise-Induced Muscle Damage. *Int J Sports Med*. 2016;37(12):937-43. https://doi.org/10.1055/s-0042-111438
2. Calleja-González J, Terrados N, Mielgo-Ayuso J, Delextrat A, Jukic I, Vaquera A, et al. Evidence-based post-exercise recovery strategies in basketball. *Phys Sportsmed*. 2016;44(1):74-8. https://doi.org/10.1080/00913847.2016.1102033
3. G. N, Halson SL, Dawson BT. Water immersion recovery for athletes: effect on exercise performance and practical recommendations. *Sports Med Auckl NZ*. 2013;43:1101-1130. https://doi.org/10.1007/s40279-013-0063-8
4. Hohenauer E, Taeymans J, Baeyens J-P, Clarys P, Clijsen R. The Effect of Post-Exercise Cryotherapy on Recovery Characteristics: A Systematic Review and Meta-Analysis. *PLoS ONE*. 2015;10. https://doi.org/10.1371/journal.pone.0139028
5. Christensen PM, Jacobs RA, Bonne T, Flück D, Bangsbo J, Lundby C. A short period of high-intensity interval training improves skeletal muscle mitochondrial function and pulmonary oxygen uptake kinetics. *J Appl Physiol*. 2016;120(11):1319-27. https://doi.org/10.1152/japplphysiol.00115.2015
6. Leeder J, Gissane C, van Someren K, Gregson W, Howatson G. Cold water immersion and recovery from strenuous exercise: a meta-analysis. *Br J Sports Med*. 2012;46(4):233-40. https://doi.org/10.1136/bjsports-2011-090061
7. Sanchez-Ureña BA, Barrantes-Brais K, Ureña-Bonilla P, Calleja-González J, Ostojic S. Effect of water immersion on recovery from fatigue: a meta-analysis. *Eur J Hum Mov*. 2015;34:1-14.
8. Higgins TR, Greene DA, Baker MK. Effects of Cold Water Immersion and Contrast Water Therapy for Recovery From Team Sport: A Systematic Review and Meta-analysis. *J Strength Cond Res*. 2017;31(5):1443-60. https://doi.org/10.1519/JSC.0000000000001559
9. Murray A, Cardinale M. Cold applications for recovery in adolescent athletes: a systematic review and meta analysis. *Extreme Physiol Med*. 2015;4:17. https://doi.org/10.1186/s13728-015-0035-8
10. Peiffer JJ, Abbiss CR, Watson G, Nosaka K, Laursen PB. Effect of cold-water immersion duration on body temperature and muscle function. *J Sports Sci*. 2009;27(10):987-93. https://doi.org/10.1080/02640410903207424
11. Yanagisawa O, Homma T, Okuwaki T, Shimao D, Takahashi H. Effects of cooling on human skin and skeletal muscle. *Eur J Appl Physiol*. 2007;100(6):737-45. https://doi.org/10.1007/s00421-007-0470-3
12. Vaile JM, Gill ND, Blazevich AJ. The effect of contrast water therapy on symptoms of delayed onset muscle soreness. *J Strength Cond Res*. 2007;21(3):697-702. https://doi.org/10.1519/00124278-200708000-00008
13. Washington LL, Gibson SJ, Helme RD. Age-related differences in the endogenous analgesic response to repeated cold water immersion in human volunteers. *Pain*. 2000;89(1):89-96. https://doi.org/10.1016/S0304-3959(00)00352-3
14. Elias GP, Wyckelsma VL, Varley MC, McKenna MJ, Aughey RJ. Effectiveness of water immersion on postmatch recovery in elite professional footballers. *Int J Sports Physiol Perform*. 2013;8(3):243-53. https://doi.org/10.1123/ijspp.8.3.243
15. Montgomery PG, Pyne DB, Hopkins WG, Dorman JC, Cook K, Minahan CL. The effect of recovery strategies on physical performance and cumulative fatigue in competitive basketball. *J Sports Sci*. 2008;26(11):1135-45. https://doi.org/10.1080/02640410802104912
16. Rowsell GJ, Coutts AJ, Reaburn P, Hill-Haas S. Effects of cold-water immersion on physical performance between successive matches in high-performance junior male soccer players. *J Sports Sci*. 2009;27(6):565-73. https://doi.org/10.1080/02640410802603855
17. Stanley J, Buchheit M, Peake JM. The effect of post-exercise hydrotherapy on subsequent exercise performance and heart rate variability. *Eur J Appl Physiol*. 2012;112(3):951-61. https://doi.org/10.1007/s00421-011-2052-7
18. Argus CK, Broatch JR, Petersen AC, Polman R, Bishop DJ, Halson S. Cold-Water Immersion and Contrast Water Therapy: No Improvement of Short-Term Recovery After Resistance Training. *Int J Sports Physiol Perform*. 2017;2016-0127. https://doi.org/10.1123/ijspp.2016-0127
19. Ascensão A, Leite M, Rebelo AN, Magalhäes S, Magalhäes J. Effects of cold water immersion on the recovery of physical performance and muscle damage following a one-off soccer match. *J Sports Sci*. 2011;29:217-225. https://doi.org/10.1080/02640414.2010.526132
20. Elias GP, Wyckelsma VL, Varley MC, McKenna MJ, Aughey RJ. of water immersion on postmatch recovery in elite professional footballers. *Int J Sports Physiol Perform*. 2013;8:243-253. https://doi.org/10.1123/ijspp.8.3.243
21. Machado AF, Ferreira PH, Micheletti JK, de Almeida AC, Lemes ÍR, Vanderlei FM, et al. Can Water Temperature and Immersion Time Influence the Effect of Cold Water Immersion on Muscle Soreness? A Systematic Review and Meta-Analysis. *Sports Med Auckl NZ*. 2016;46(4):503-14. https://doi.org/10.1007/s40279-015-0431-7
22. Kwiecien SY, McHugh MP, Howatson G. The efficacy of cooling with phase change material for the treatment of exercise-induced muscle damage: pilot study. *J Sports Sci*. 2018;36(4):407-13.
23. Stevens CJ, Kittel A, Sculley DV, Callister R, Taylor L, Dascombe BJ. Running performance in the heat is improved by similar magnitude with pre-exercise cold-water immersion and mid-exercise facial water spray. *J Sports Sci*. 2017;35(8):798-805. https://doi.org/10.1080/02640414.2016.1192294
24. Johnston RD, Gabbett TJ, Jenkins DG. Influence of playing standard and physical fitness on activity profiles and post-match fatigue during intensified junior rugby league competition. *Sports Med - Open*. 2015;1(1):18. https://doi.org/10.1186/s40798-015-0015-y
25. Rowsell GJ, Coutts AJ, Reaburn P, Hill-Haas S. Effect of post-match cold-water immersion on subsequent match running performance in junior soccer players during tournament play. *Journal of Sports Sciences*, 2011;29:1–6. https://doi.org/10.1080/02640414.2010.512640
26. Belkadi A, Remaoun M, Benbernou O. The Perception of the Use of (Ict) on the Acquisition of New Teaching Skills According to (Teachers, Student Trainees). *In the Physical Education and Sports*. 2017;1: 28-32.
27. Chrara L, A.Raoui R, Belkadi A, Asli H, Benbernou O. Effects of caloric restriction on anthropometrical and specific performance in highly-trained university judo athletes. *Arab Journal of Nutrition and Exercise (AJNE)*, 2018;3:105-118. https://doi.org/10.18502/ajne.v3i3.3669
28. Ihsan M, Watson G, Abbiss CR. What are the Physiological Mechanisms for Post-Exercise Cold Water Immersion in the Recovery from Prolonged Endurance and Intermittent Exercise? *Sports Med Auckl NZ*. 2016;46(8):1095-109. https://doi.org/10.1007/s40279-016-0483-3
29. General Assembly of the World Medical Association.

World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *J Am Coll Dent*. 2014;81(3):14-8.
30. Wilhelm Hoppe M, Brochhagen J, Baumgart C, Bauer J, Freiwald J. Differences in Anthropometric Characteristics and Physical Capacities Between Junior and Adult Top-Level Handball Players. *Asian Journal of Sports Medicine*, 2017;In Press. https://doi.org/10.5812/asjsm.60663
31. Karan V, Rakovac A, Karan M, Popović M, Klašnja J, Lukač D. Evaluation of body composition and muscular strength in different sports. *Med Pregl*. 2017;70(5-6):150-4. https://doi.org/10.2298/MPNS1706150K
32. Houcine A, Ahmed A, Saddek Z. Designing a Software to Count the Body Composition and Somatotype and its Role in Pursing the Morphological State of Spotsmen. *AASRI Procedia*. 2014;8:38-43. https://doi.org/10.1016/j.aasri.2014.08.007
33. Hammami M, Negra Y, Billaut F, Hermassi S, Shephard RJ, Chelly MS. Effects of Lower-Limb Strength Training on Agility, Repeated Sprinting With Changes of Direction, Leg Peak Power, and Neuromuscular Adaptations of Soccer Players. *J Strength Cond Res*. 2018;32(1):37-47. https://doi.org/10.1519/JSC.0000000000001813
34. Katch VL, Katch FI. A simple antrhopometric method for calculating segmental leg limb volume. *Res Q*. 1974;45(2):211-4. https://doi.org/10.1080/10671188.1974.10615262
35. Mudie KL, Gupta A, Green S, Hobara H, Clothier PJ. A Comparison of Vertical Stiffness Values Calculated from Different Measures of Center of Mass Displacement in Single-Leg Hopping. *J Appl Biomech*. 2017;33(1):39-47. https://doi.org/10.1123/jab.2016-0037
36. Tidhar D, Armer JM, Deutscher D, Shyu C-R, Azuri J, Madsen R. Measurement Issues in Anthropometric Measures of Limb Volume Change in Persons at Risk for and Living with Lymphedema: *A Reliability Study. J Pers Med.* 2015;5(4):341-53. https://doi.org/10.3390/jpm5040341
37. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement jump tests. *J Strength Cond Res*. 2004;18(3):551-5. https://doi.org/10.1519/00124278-200408000-00028
38. Simmons G, Cooper S, Research JB, Muse D. Enhancing methods for the delayed onset muscle soreness (DOMS) pain model. *J Pain*. 2018;19(3):S81. https://doi.org/10.1016/j.jpain.2017.12.196
39. Glasgow PD, Ferris R, Bleakley CM. Cold water immersion in the management of delayed-onset muscle soreness: Is dose important? A randomised controlled trial. *Phys Ther Sport*. 2014;15(4):228-33. https://doi.org/10.1016/j.ptsp.2014.01.002
40. Delextrat A, Calleja-González J, Hippocrate A, Clarke ND. Effects of sports massage and intermittent cold-water immersion on recovery from matches by basketball players. *J Sports Sci*. 2013;31(1):11-9. https://doi.org/10.1080/02640414.2012.719241
41. Lauber C, Hickle S, Jargstorf J, West C. Effect of Cold Water Immersion or Contrast Water Therapy on Muscle Soreness After Exercise: 3330 Board #235 June 2 2. *Medicine & Science in Sports & Exercise*, 2017;49:951. https://doi.org/10.1249/01.mss.0000519594.90624.f3
42. Versey NG, Halson SL, Dawson BT. Water immersion recovery for athletes: effect on exercise performance and practical recommendations. *Sports Med Auckl NZ*. 2013;43(11):1101-30. https://doi.org/10.1007/s40279-013-0063-8
43. Ascensão A, Leite M, Rebelo AN, Magalhäes S, Magalhäes J. Effects of cold water immersion on the recovery of physical performance and muscle damage following a one-off soccer match. *J Sports Sci*. 2011;29(3):217-25. https://doi.org/10.1080/02640414.2010.526132
44. Sánchez-Ureña B, Martínez-Guardado I, Crespo C, Timón R, Calleja-González J, Ibañez SJ, et al. The use of continuous vs. intermittent cold water immersion as a recovery method in basketball players after training: a randomized controlled trial. *Phys Sportsmed*. 2017;45(2):134-9. https://doi.org/10.1080/00913847.2017.1292832
45. Elias GP, Wyckelsma VL, Varley MC, McKenna MJ, Aughey RJ. Effectiveness of water immersion on postmatch recovery in elite professional footballers. *Int J Sports Physiol Perform*. 2013;8(3):243-53. https://doi.org/10.1123/ijspp.8.3.243
46. Wang H, Siemens J. TRP ion channels in thermosensation, thermoregulation and metabolism. *Temperature* 2015;2:178–87. https://doi.org/10.1080/23328940.2015.1040604
47. Knowlton WM, Palkar R, Lippoldt EK, McCoy DD, Baluch F, Chen J, et al. A Sensory-Labeled Line for Cold: TRPM8-Expressing Sensory Neurons Define the Cellular Basis for Cold, Cold Pain, and Cooling-Mediated Analgesia. *J Neurosci*. 2013;33(7):2837-48. https://doi.org/10.1523/JNEUROSCI.1943-12.2013
48. Proudfoot CJ, Garry EM, Cottrell DF, Rosie R, Anderson H, Robertson DC, et al. Analgesia Mediated by the TRPM8 Cold Receptor in Chronic Neuropathic Pain. *Curr Biol*. 2006;16(16):1591-605. https://doi.org/10.1016/j.cub.2006.07.061
49. Abdelkader G, Madani R, Adel B, Bouabdellah S. Sporting events among the disabled between excellence and ideal in motor performance. *Int J Phys Educ Fit Sports*. 2018;7(3):66-71. https://doi.org/10.26524/ijpefs1837
50. Mohamed KS, Mohamed K, Mohammed S, Mokrani D, Belkadi A. The Effect of Heavy Weight Training on Physiological Abilities of Soccer Players Under the Age 21 Years Old. *Acta Fac Educ Phys Univ Comen.* 2019;59(1):33-43. https://doi.org/10.2478/afepuc-2019-0004
51. Zagatto AM, de Paula Ramos S, Nakamura FY, de Lira FS, Lopes-Martins RÁB, de Paiva Carvalho RL. Effects of low-level laser therapy on performance, inflammatory markers, and muscle damage in young water polo athletes: a double-blind, randomized, placebo-controlled study. *Lasers Med Sci*. 2016;31(3):511-21. https://doi.org/10.1007/s10103-016-1875-1
52. Wilcock IM, Cronin JB, Hing WA. Physiological response to water immersion: a method for sport recovery? *Sports Med Auckl NZ*. 2006;36(9):747-65. https://doi.org/10.2165/00007256-200636090-00003
53. Belkadi A, Othman B, Mohamed S, Abdelhafid L, M BH, Gleyse J. Contribution to the Identification of the Professional Skills Profile of Coaches in the Algerian Sport Judo System. *Int J Sports Sci*. 2015;5(4):145-50.
54. Berria M, Bachir K, Eddine SN, Adel B. Study of LDH adaptations associated with the development of Speed endurance in basketball players U19. *Int J Appl Exerc Physiol*. 2018;7(3):35-43.

Information about the authors:

Mokhtar M.; https://orcid.org/0000-0002-9832-0840; mokhtar.mim@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem; 27000 Mostaganem, Algeria.

Adel B.; (Corresponding author)**;** https://orcid.org/0000-0002-8715-2036; Adel.belkadi@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem; 27000 Mostaganem, Algeria.

Wahib B.; https://orcid.org/0000-0002-4622-4582; wahib.beboucha@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem; 27000 Mostaganem, Algeria.

Hocine A.; https://orcid.org/0000-0003-2657-1795; asli.houcine_sport@yahoo.fr; Institute of Physical Education And Sport, University of Oran; 31000 Oran, Algeria.

Othman B.; https://orcid.org/0000-0003-1883-6917; benbernouothmane@yahoo.fr; Institute of Physical Education And Sport, University of Mostaganem-University of Mostaganem; 27000 Mostaganem, Algeria.

Mohamed S.; https://orcid.org/0000-0003-3448-5299; mohamed.sebbane@univ-mosta.dz; Institute of Physical Education And Sport, University of Mostaganem-University of Mostaganem; 27000 Mostaganem, Algeria.

Cite this article as:
Mokhtar M, Adel B, Wahib B, Hocine A, Othman B, Mohamed S. The effects of tow protocol cold water immersion on the post match recovery and physical performance in well-trained handball players. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):288-295.
https://doi.org/10.15561/18189172.2019.0603

Received: 30.08.2019
Accepted: 25.09.2019; Published: 30.09.2019

PSYCHOLOGY medical-biological problems of physical training and sports

The effects of physical education on changes of basic motor skills of female students in the fifth grade of elementary school

Nikšić E.[1ABCDE], Beganović E.[2ABCDE], Rašidagić F.[2ACE], Mirvić E.[2CDE], Joksimović M.[3ADE]

[1]*Faculty of Educational Sciences, University of Sarajevo, Bosnia and Herzegovina*
[2]*Faculty of Sport and Physical Education, University of Sarajevo, Bosnia and Herzegovina*
[3]*Faculty of Physical Education and Sport, University of East Sarajevo, Bosnia and Herzegovina*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: Thanks to the positive health effects of physical exercise, physical education is an integral part of the education system, with two hours per week, which is insufficient to achieve an optimal effect in transforming the anthropological status of children. The aim of the research was to determine the effects of regular and modified physical education with the application of contents from sports games (basketball, volleyball and handball) in the duration of one semester to changes in basic motor skills in pupils of the fifth grade of elementary school.

Material: The study included N = 106 students of the V class, aged 10 to 11 years, clinically and mentally healthy, and with no pronounced morphological and locomotor impairments. The sample of examinees was divided into two subgroups. The first was an experimental group of 53 students, who carried out physical education classes according to the modified plan and program of sports games (basketball, volleyball and handball) for a semester. The other was a control group of 53 students who attended regular classes from physical education according to the current curriculum.

Results: The results of the research at the descriptive level showed noticeable differences between the same groups in the final versus the initial measurements. Based on the results of the t-test for the control and experimental group, it can be concluded that there have been statistically significant changes in values on all variables of basic motor in the final compared to the initial measurement. By analyzing the results of the t-tests, it can be seen that the groups differ in the initial measurement only in one basic motor variable, MTAPN, and this difference is statistically significant in favor of the control group. In the final measurement, there are no significant differences between the control and the experimental group in the average values of all variables of basic motoring.

Conclusions: Improving basic motor skills depends on the teacher's ability, the ability to transform the age with which he is working, and the success of certain training processes. The modified program of the experimental group has led to changes and thus proves the significant effect of the group's work program.

Keywords: physical education, modified program, sports games, motor skills, students.

Introduction

The need for physical exercise is one of the general biological needs of an organism and plays an important role in its life. The connection of physical activity with the state of human health is indisputable, it is the basic factor in determining the level of changes in the organism and the condition of its bone, muscle, cardiovascular and nervous system. The process of physical exercise leads to certain transformations and enhancements in functional abilities and individual organic systems [1]. Coordination is the ability to control the movements of the whole body or parts of the locomotor system, and is characterized by the speed and precise execution of complex motor assignments [2]. The methodology for the development of coordination in the period of 10-11 years has the following guidelines: increase the level of coordination capacities compared to the previous period, develop coordination used in the learning of sports skills, and encourage children to perform exercises for the development of coordination in their free time.

Coordination exercises require a high concentration. They affect the nervous system and quickly tickle it. For this reason, it is best to train the coordination at the beginning of the main part or even at the end of the introductory part of the training (class). During the exercise, it is necessary to take some breaks for recovery between repetitions. Certain processes of exercise significantly influence changes in different human traits, abilities and knowledge. But there is always the current question: "How much, what and how to practice the changes, and how to control the variability in quantitative and qualitative terms" [3]. Speed is the ability to perform one or more movements in a shorter period of time [2]. In order to be able to develop a speed that is genetically limited in good measure, the following conditions must be met: morphological, energy, psychological, coordination techniques, power levels, sustainability and flexibility.

The sensitive stage in the development of speed in girls is between 7 and 11 years. The development of speed in girls lasts up to 14 years and after that stagnates if girls do not deal with systematic physical exercise. A similar sensitivity phase is with boys. Only boys have an intensive period of 7-9 years, and after 14th they continue to develop speeds up to 18 years. In the development of speed, the following methodical instructions must be followed: to carry out the learned grid structures faster than the

doi:10.15561/18189172.2019.0604

average speed; first it is necessary to train at a speed less than the maximum, and when the technique is adopted at a high level, then the technique can be performed at the maximum speed, train according to the principles: from easy to heavy, from simple to complex and from known to unknown, connect speed exercises with techniques of a particular sport, change speed development exercises, change the conditions in which the speed is developing, increase the number of repetitions, and not the duration of repetition, use long pauses. Rest in principle lasts from one to three minutes, use long and basic warming and take advantage of the sensible phases of the development of speed. In children, it is recommended that exercises are not performed at the maximum intensity, because performing exercises with maximum intensity in children causes the emergence of the so-called. speed barriers [4].

Power can be defined as the ability to overcome resistance and force. There are several types of action manifestations of force: explosive force, maximum power, elastic strength, repetitive force, static power [2]. The sensitive phase of the development of individual power types is diverse. Thus, for the explosive strength, the sensitive phase is from 12-13 years, from 12-15. During the year, static power is growing faster in boys than in girls. In developing children's strength, particular methodical instructions must be followed. Power exercises should have the character of the game, because the game is a major driver of activity for children. Exercising in groups is much more effective and makes satisfaction. The exercises must correspond to the biological development of the child, where exercises must be individualized. The intensity and extent of the sea must be adapted to the children. In addition to the power exercises in the preparation part of the clock, a positive effect would cause the application of the game content, where the accent would be in effect, in the "B" part of an hour. The methodological instructions of the training aim to alert us that the systematic development of power should only begin when the active and passive part of the movement system takes the appropriate strength. In the development of strength in children and young people, it is necessary to influence the development of repetitive power by applying dynamic exercises.

The most suitable methods used to develop the power are: low-load out-load methods (up to 30 s), medium-load circuits in the form of circular training, up to 10 drills, and up to 20 repetitions, high- 10 exercises with 10 reps [4]. Flexibility is the ability to perform maximum amplitudes of movement in an ankle or a series of joints. The basic types of flexibility are dynamic, static passive and statically active [2]. At the age of 6-10. The mobility of shoulders and hooks is reduced, and dynamic stretching of the same joints is necessary at that time. The spine column in the period of 8 and 9 years has the greatest flexibility. At the age of 6-10 it is necessary to avoid static stretching because children of that age are hard to maintain concentration and relaxation, which is crucial for these exercises. In the period from 10-13. It is important to increase the flexibility training, since increased exercise activity without increased application of stretching exercises can lead to a decrease in the amplitude of the movement. In the age of accelerated growth and development, it is crucial to apply flexibility training exercises, because then there is an accelerated bone growth, and muscles and tendons can not be tracked. Basic methodological guidelines for the development of childhood flexibility: to apply flexibility in a moderate extent, to connect the development of flexibility and strength, to work on the flexibility of precisely determined joints and to apply dynamic flexibility exercises in training children [4]. Physical education of two hours a week can hardly fully satisfy the need for movement. In some instances, there is a lack of motivation for physical exercise in children, and they try to avoid active participation in classes in all possible ways. In the physical education classes, students have four sports games: handball, basketball, football and volleyball. Sports games are characterized by varied natural movements. All these movements are applied in the conditions of cooperation between the teammates.

The effectiveness of the game depends to a great extent on the speed of movement, perception of space and players in it, from the adoption of the technique of movement, and the level of motor and general abilities. The place of sports games in the teaching of physical education is not accidental. Participation in sports games is characterized by intense muscular, psychological and functional activity, which results in a positive impact on the biopsychosocial development of the child [5]. Skender, [6] in his doctoral dissertation: "Transformation processes of motor skills and anthropological characteristics under the influence of seven-month treatment in students of the third and fourth grade" on a sample of 206, divided into two subusers (experimental and control), applied standard and experimental treatment for a period of seven months. The results showed that three-hour experimental treatment performed by professors of physical education showed better results than the standard physical education program conducted by class teachers. Stanković and Hadžikadunić, [7] in their research: "The influence of programmed physical education on the changes in motor skills in one-year students", resulted in the result that 70 hours of physical and health education in one year led to changes in all tested motor skills. The variables were the capabilities covered by tests from the eurofit battery test. Kucuk, [8], on a sample of 110 pupils (boys and girls), 11 - 13 years of age, determines statistically significant changes in the structural process of motor dimensions of initial and final measurement, under the influence of the curriculum. A discriminatory analysis designed to define quantitative changes occurring at two time points indicates that the variables for the estimation of equilibrium (flamingo), long jump (explosive power), lying seat (repetitive force of the hull) and then the variable 10x5 statistically significantly changed. Lakota, [9] in his master's thesis on the sample of 82 handball players 11-14 years of age tried to determine the qualitative and quantitative changes in basic situational motor skills created under the influence of the three-month program of handball. For this purpose, methods for qualitative-structural changes were used: LSDF model, CRAMERT model, QDIFFI model and Krzanow model, and for quantitative GK criteria. A 52-course handball program program produced statistically significant changes in the treated areas. Skender, et al., [10] in his paper "Effects of programmed classes on improving motor skills in pupils of younger age groups", found that the programmed three-hour training for seven and seven months caused positive effects on the improvement of motor skills that were included in the testing. Hadžikadunić, [11], on a sample of 146 male students, identified transformation processes under the influence of programmed physical and health education for 69 hours of instruction in basic motor, situational and motor skills and functional abilities of students of the eighth grade.

A system of variables of 8 tests for basic motor abilities and 9 tests for the assessment of specific motor abilities was used, and one test for the evaluation of functional abilities. It was found that programmed teaching has a positive effect on improving basic motor, situational and functional abilities between two measurements. Batričević, [12] in his paper: "A discriminatory analysis of the motor and functional abilities of sports active and inactive students", on a sample of 64 students, divided into two subusers (sports active and inactive students). He established the existence of a difference between the two subroutines. The results of the study show that sports active students are better in tests for estimating explosive power, segmental velocity, vital lung capacity, and systolic and diastolic blood pressure. Mladenović, [13], in his paper " The structural changes in sports games during physical and health education classes" on the sample of 152 students, carried out the contents of sports games in the teaching of physical education in the course of one school year. By applying the treatment, the level of structural changes in basic and specific motors was attempted.

The results of this program have shown a general, systematic, continuous reconstruction of general and specific motor abilities, therefore the transformation process is responsible, although not in all situations to the same extent. The weakest effects are captured in the case of football. Nikolić et al., [14] in his paper: "The Impact of Experimental Treatment on Some Motor Performance of Fourth-Grader Students", on a sample of 104 students, applied treatment to the change in motor skills in tests for estimating the segmental velocity of the extremities, the explosive force . The Chinese treatment did not cause changes in the flexibility and static strength variables, which are influenced by the longitudinal dimension of the skeleton, that is, the static strength test is too heavy for the selected sample. Malacko and Pejić, [15] have studied the changes of biomotor pupils aged 11 years under the influence of the experimental program of sports games in relation to the standard program of physical education. The sample was made up of 252 male students, who were divided into a control and experimental group. A system of 33 variables (12 morphological and 21 for the estimation of motor and functional abilities) was used. The experimental program was saturated with the content of sports games, and the results indicate that the morphological system contributes to the equal differentiation of the group, whereas in the motor space better results were shown by the experimental group of 14 variables that showed a statistically significant difference in 13 variables were better than the experimental group.

The aim of the research is to determine the effects of regular and modified physical education with the application of contents from sports games (basketball, volleyball and handball) in the duration of one semester to changes in basic motor skills in pupils of the fifth grade of elementary school.

Material and Methods

Participants

The study was conducted on a sample of N = 106 pupils in V grade, female, aged 10 to 11 years, clinically and mentally healthy, and with no pronounced morphological and locomotor impairments. The sample of examinees was divided into two subgroups, an experimental (53 pupils) and a control group (53 students). The experimental group conducted classes according to the changed curriculum. The program included sports games from handball, basketball and volleyball. The control group carried out the teaching according to the current curriculum.

Research Design

The variables used in this study consisted of 15 motor variables:

- Variables for estimating the frequency of the movement (Tapping by hand - MTAP; Tapping the leg - MTAPN; Tapping the feet against the wall - MTAPNZ).
- Variables for flexibility assessment (Stick turn - MFLISK; Reach in the seat - MBFDS; Precoding right - MPD).
- Variables for estimating explosive power (Long Distance Jump - MFESDM; High Jump from the Site - MFESUM; High Speed Sprint 20m - MFE2OV).
- Variables for estimating repetitive power (Leak test-test - MRCLDM; Test squad for 40 seconds - MFRDC; Sketches - MFRSKL).
- Variables for assessing coordination (Steps aside - MAGKUS; Magnetic Test - MAGTUP; Polygon Background - MRGEPOL).

Work program

During the first semester, three teaching units were processed as part of regular classes: athletics, basketball and volleyball. A total of 35 teaching hours of regular physical education were held, of which 12 hours of athletics, 12 hours of basketball, 11 hours of volleyball. The program of additional classes through the basketball, volleyball and handball sports games consisted of a modified curriculum from basketball: adding and catching balls from basketball, running a ball with a stop, a basketball technique, a low-lead technique, a kick-off practice with zipper positions, zigzag guiding, one - handed addition, moving the ball with arms in motion, running the ball with stop in the position of the shot, ball manipulation, pivoting technique with the ball, straight line guidance from high to low, and vice versa. From the volleyball sports, some teaching units were used, for example: adding a hammer, fingering over the net, school service, mini volleyball, hammering over the head, refusing the ball from the wall, adding alternating fingers - a hammer, school service with six and nine meters, jumping from dockyards on the net, shooting a basket with a hammer. From the handball, the teaching units worked as follows: foreclosure, lateral addition, jumping, kicking on the goal, slalom, handball, straight tracking, mini handball, goal kicking - seven, manipulation with a handball, Shade Adding, Adding To The Triples Game 1: 1 Shot on goal. Only girls were involved in this program and for this reason football was not taken as a sport game.

Statistical Analysis

A descriptive statistical procedure was applied in the data processing process. The following descriptive parameters are calculated: Minimum, Maximum, Mean, Standard Deviation, while to calculate the distribution: Skewness and Kurtosis. The T-test determined differences in variables for assessing the motor abilities of the initial and final measurement of the control and experimental group. Statistical data processing in this study was done using computer software SPSS statistics 20.0 in Windows 10.

Results

Table 1 gives an overview of the average values of the control and experimental group on the basic motor variables in the initial and final measurements. There are noticeable differences between groups in different measurement situations on all these variables. There are also differences between the average values of the same group in the final compared to the initial measurements. Of course, these differences are present at the descriptive level and can only reflect random variations. According to the values of the flattening and curvature index in Table 1, it can be concluded that most of the basic motor variables in initial and final measurements are normally and symmetrically distributed and can be further analyzed.

However, according to the values of the Skewness and the Kurtosis, some variables are noticeable and deviations. Thus, with acceptable values of Skewness, and values of Kurtosis greater than 1, symmetrical but

Table 1. Display of average values and deviation measures on basic motor variables - Control and experimental group initially and final

Variables	Group	Min.		Max.		Mean		Std.Dev.		Skewness		Kurtosis	
		IT	FT	IT	FT	IT	FT	IT	FT	IT	FT	IT	FT
MTAP	Control	21.00	24.00	34.00	36.00	27.30	29.85	2.74	2.82	0.32	0.34	-0.04	-0.51
	Experimental	20.00	21.00	37.00	37.00	28.09	30.21	4.01	3.50	0.14	-0.21	-0.27	0.17
MTAPN	Control	15.00	20.00	30.00	36.00	24.57	26.70	2.79	2.84	-0.78	0.49	1.71	1.49
	Experimental	15.00	16.00	29.00	33.00	22.66	26.68	2.71	3.22	-0.28	-0.38	0.57	1.00
MTAPNZ	Control	12.00	16.00	22.00	26.00	18.74	21.26	2.25	2.53	-0.88	-0.35	0.96	-0.28
	Experimental	13.00	14.00	30.00	32.00	19.36	21.53	3.26	3.10	0.57	0.83	1.22	2.31
MFLISK	Control	29.00	29.00	106.00	101.00	71.89	62.96	15.91	14.92	0.08	0.42	0.23	0.33
	Experimental	27.00	15.00	109.00	98.00	74.57	63.40	18.63	17.72	-0.27	-0.32	-0.37	-0.06
MBFDS	Control	3.00	6.00	50.00	52.00	21.30	23.28	7.83	7.75	0.63	0.66	2.84	2.87
	Experimental	2.00	6.00	32.00	33.00	19.38	21.30	7.06	6.64	-0.51	-0.64	-0.44	-0.32
MPD	Control	14.00	22.00	67.00	73.00	42.17	46.98	11.35	10.61	-0.14	0.08	0.02	0.22
	Experimental	19.00	24.00	60.00	64.00	42.36	45.96	9.91	10.06	-0.36	-0.29	-0.19	-0.52
MFESDM	Control	100.00	105.00	195.00	210.00	147.17	157.26	24.91	24.49	-0.01	-0.13	-0.98	-0.37
	Experimental	90.00	110.00	195.00	195.00	148.68	159.15	25.06	22.91	-0.23	-0.37	-0.56	-0.59
MFESUM	Control	15.00	17.00	39.00	44.00	26.72	29.53	5.22	5.44	-0.03	0.34	0.15	0.60
	Experimental	14.00	18.00	42.00	43.00	26.49	29.72	5.57	5.38	0.48	0.48	1.45	0.79
MFE20V	Control	3.57	3.53	5.38	5.09	4.31	4.10	0.41	0.36	0.36	0.53	-0.54	-0.28
	Experimental	3.62	3.44	5.88	5.38	4.41	4.08	0.55	0.47	0.92	0.94	0.15	0.32
MRCLDM	Control	10.00	15.00	27.00	31.00	20.60	23.45	4.03	4.01	-0.36	0.01	-0.27	-0.67
	Experimental	10.00	15.00	32.00	33.00	21.42	24.49	4.77	4.25	0.00	0.20	0.34	-0.51
MFRDC	Control	20.00	23.00	45.00	47.00	31.25	35.43	5.57	5.42	0.05	-0.53	-0.36	-0.04
	Experimental	10.00	21.00	46.00	49.00	29.72	35.04	7.60	6.59	-0.48	-0.29	0.30	-0.51
MFRSKL	Control	1.00	1.00	36.00	41.00	8.21	12.00	8.78	10.48	1.39	0.99	1.30	0.20
	Experimental	1.00	1.00	40.00	53.00	11.04	15.81	9.86	11.99	1.04	0.88	0.74	0.89
MAGKUS	Control	10.50	9.68	14.87	14.56	12.87	12.01	1.17	1.18	-0.15	0.12	-0.91	-0.79
	Experimental	9.28	9.15	16.19	15.00	13.04	11.97	1.61	1.38	-0.32	0.00	-0.63	-0.56
MAGTUP	Control	27.06	25.56	39.24	36.34	31.18	29.44	2.73	2.50	0.70	1.02	0.28	0.71
	Experimental	25.07	24.03	45.06	39.06	32.17	29.93	4.02	3.30	0.62	0.53	0.65	-0.03
MRGEPOL	Control	12.69	9.63	40.69	35.38	22.82	17.78	6.52	5.22	0.98	1.24	0.85	1.97
	Experimental	12.75	10.97	46.93	35.06	22.08	18.47	6.57	5.44	1.31	1.12	3.21	1.30

Legend: IT-initial testing, FT-final testing.

somewhat elongated (leptocutaneous) distribution of the results of the control group on the MTAPN variable was observed, both in the initial and final measurements and in the experimental group on the MFESUM variable in the initial measurement. In the final measurement, MFESUM was normally distributed.

In the initial measurement, it was found that the Skewness and Kurtosis of the control group were greater than 1 when the MFRSKL variable was concerned, indicating leptocutaneous and mildly positive asymmetric distribution while the experimental group Kurtosis is acceptable and the MFRSKL Skewness indicates mild positive asymmetry. When the distribution of results on the variable MRGEPOL is positive, the control group is positively asymmetric and elongated (Skewness and Kurtosis greater than 1) in the final measurement, and in the experimental group in the initial measurement. However, it is noteworthy that these deviations of the normalities are mild since the Kurtosis and the Skewness do not deviate drastically from the reference interval but are slightly above the boundary. For this reason, no transformations have been made because the greater benefit of retaining the original values of these variables and their entering into further analysis is estimated.

From the above table of t-tests, it can be seen that groups differ in the initial measurement only in one basic motor variable, MTAPN. On average (the table with average values, column M), the control group subjects have higher values on this variable ($M_{control}$ = 24.57 a $M_{experimental}$ = 22.66). This difference in MTAPN is statistically significant in favor of the control group. In other variants of basic motor, there are no statistically significant differences between the control and experimental groups in the initial measurement.

As seen from the above table of t-tests, none of the t-tests is statistically significant at any level of significance. Thus, it can be concluded that in the final measurement there are no significant differences between

Table 2. T-test value basic motor for independent samples control and experimental group initial measurement

Variables	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
MTAP	7.47	0.01	-1.19	104.00	0.24	-0.79	0.67	-2.12	0.53
			-1.19	91.91	0.24	-0.79	0.67	-2.12	0.53
MTAPN	0.05	0.83	3.57	104.00	0.00	1.91	0.53	0.85	2.97
			3.57	103.91	0.00	1.91	0.53	0.85	2.97
MTPNZ	4.77	0.03	-1.15	104.00	0.25	-0.62	0.54	-1.70	0.46
			-1.15	92.31	0.26	-0.62	0.54	-1.70	0.46
MFLISK	1.75	0.19	-0.80	104.00	0.43	-2.68	3.36	-9.35	3.99
			-0.80	101.52	0.43	-2.68	3.36	-9.35	4.00
MBFDS	0.12	0.73	1.33	104.00	0.19	1.92	1.45	-0.95	4.80
			1.33	102.89	0.19	1.92	1.45	-0.95	4.80
MPD	0.48	0.49	-0.09	104.00	0.93	-0.19	2.07	-4.29	3.92
			-0.09	102.15	0.93	-0.19	2.07	-4.29	3.92
MFESDM	0.11	0.74	-0.31	104.00	0.76	-1.51	4.85	-11.13	8.12
			-0.31	104.00	0.76	-1.51	4.85	-11.13	8.12
MFESUM	0.00	0.98	0.22	104.00	0.83	0.23	1.05	-1.85	2.31
			0.22	103.56	0.83	0.23	1.05	-1.85	2.31
MFE20V	3.13	0.08	-1.07	104.00	0.29	-0.10	0.09	-0.29	0.09
			-1.07	95.61	0.29	-0.10	0.09	-0.29	0.09
MRCLDM	0.21	0.65	-0.95	104.00	0.35	-0.81	0.86	-2.51	0.89
			-0.95	101.18	0.35	-0.81	0.86	-2.51	0.89
MFRDC	2.85	0.09	1.18	104.00	0.24	1.53	1.29	-1.04	4.10
			1.18	95.34	0.24	1.53	1.29	-1.04	4.10
MFRSKL	0.66	0.42	-1.56	104.00	0.12	-2.83	1.81	-6.43	0.77
			-1.56	102.62	0.12	-2.83	1.81	-6.43	0.77
MAGKUS	5.83	0.02	-0.62	104.00	0.53	-0.17	0.27	-0.71	0.37
			-0.62	95.06	0.53	-0.17	0.27	-0.71	0.37
MAGTUP	7.20	0.01	-1.48	104.00	0.14	-0.99	0.67	-2.31	0.34
			-1.48	91.48	0.14	-0.99	0.67	-2.31	0.34
MRGEPOL	0.01	0.92	0.58	104.00	0.57	0.73	1.27	-1.79	3.26
			0.58	103.99	0.57	0.73	1.27	-1.79	3.26

Table 3. T-test value basic motor for independent samples control and experimental group final measurement

Variables	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
MTAP	1.22	0.27	-0.58	104.00	0.56	-0.36	0.62	-1.58	0.87
			-0.58	99.57	0.56	-0.36	0.62	-1.58	0.87
MTAPN	1.27	0.26	0.03	104.00	0.97	0.02	0.59	-1.15	1.19
			0.03	102.39	0.97	0.02	0.59	-1.15	1.19
MTPNZ	0.52	0.47	-0.48	104.00	0.63	-0.26	0.55	-1.35	0.83
			-0.48	99.90	0.63	-0.26	0.55	-1.36	0.83
MFLISK	1.68	0.20	-0.14	104.00	0.89	-0.43	3.18	-6.74	5.88
			-0.14	101.06	0.89	-0.43	3.18	-6.75	5.88
MBFDS	0.01	0.92	1.41	104.00	0.16	1.98	1.40	-0.80	4.76
			1.41	101.61	0.16	1.98	1.40	-0.80	4.76
MPD	0.00	0.96	0.51	104.00	0.61	1.02	2.01	-2.96	5.00
			0.51	103.71	0.61	1.02	2.01	-2.96	5.00
MFESDM	0.14	0.71	-0.41	104.00	0.68	-1.89	4.61	-11.02	7.25
			-0.41	103.54	0.68	-1.89	4.61	-11.02	7.25
MFESUM	0.20	0.66	-0.18	104.00	0.86	-0.19	1.05	-2.27	1.90
			-0.18	103.99	0.86	-0.19	1.05	-2.27	1.90
MFE20V	2.54	0.11	0.22	104.00	0.83	0.02	0.08	-0.14	0.18
			0.22	97.11	0.83	0.02	0.08	-0.14	0.18
MRCLDM	0.22	0.64	-1.29	104.00	0.20	-1.04	0.80	-2.63	0.56
			-1.29	103.64	0.20	-1.04	0.80	-2.63	0.56
MFRDC	3.02	0.09	0.34	104.00	0.74	0.40	1.17	-1.93	2.72
			0.34	100.26	0.74	0.40	1.17	-1.93	2.72
MFRSKL	0.30	0.59	-1.74	104.00	0.08	-3.81	2.19	-8.15	0.53
			-1.74	102.17	0.08	-3.81	2.19	-8.15	0.53
MAGKUS	0.86	0.35	0.16	104.00	0.87	0.04	0.25	-0.45	0.53
			0.16	101.61	0.87	0.04	0.25	-0.45	0.53
MAGTUP	5.24	0.02	-0.87	104.00	0.39	-0.49	0.57	-1.62	0.64
			-0.87	96.83	0.39	-0.49	0.57	-1.62	0.64
MRGEPOL	0.01	0.92	-0.67	104.00	0.51	-0.69	1.04	-2.75	1.36
			-0.67	103.82	0.51	-0.69	1.04	-2.75	1.36

the control and the experimental group in the average values of all variants of basic motoring. It is notable that there are no differences between groups and variables for which there were no statistically significant differences in the initial measurement as well as for the variables for which significant differences in the initial measurement were shown. As previous analyzes have shown, in the initial measurement it has been proven that the control group has statistically significantly higher values on the MTAPN variables ($M_{control}$ = 24.57 and the $M_{experimental}$ = 22.66). However, the significance of the difference is lost in the final measurement, and it can be concluded that the effect of the experimental group program has led to changes that have resulted in a significant difference in the benefit of the control group.

In the next part of the paper t-tests for dependent samples for the control group were made in order to see if there were changes in the average values of the basic motor after the work program, ie, in the final measurement and whether these changes are statistically significant.

As can be seen from the table above, all t-tests are statistically significant at a level far below 1%. So, when it comes to the control group, there were statistically significant changes in the values on all variables of basic motor in the final versus the initial measurement.

As seen from the table above, all t-tests are statistically significant at levels that are far less than 1%. Thus, in the experimental group there were significant changes in values on all variables of basic motor in the final measurement and in relation to the initial measurement. Although similar changes occurred among the control group subjects, this finding is in favor of the experimental group, as it demonstrates the significant effect of the program's work program. Thus, after the program of work in the experimental group there was significant increase of values on the variables MTAP, MTAPN, MTPNZ,

Table 4. T-test values basic motor control group

Variables	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
MTAP	96.40	105.00	0.00	28.58	27.99	29.16
MTAPN	87.98	105.00	0.00	25.63	25.05	26.21
MTAPNZ	76.34	105.00	0.00	20.00	19.48	20.52
MFLISK	43.41	105.00	0.00	67.42	64.34	70.50
MBFDS	29.35	105.00	0.00	22.29	20.79	23.80
MPD	40.99	105.00	0.00	44.58	42.42	46.73
MFESDM	62.44	105.00	0.00	152.22	147.38	157.05
MFESUM	52.73	105.00	0.00	28.12	27.07	29.18
MFE20V	109.28	105.00	0.00	4.20	4.13	4.28
MRCLDM	53.36	105.00	0.00	22.03	21.21	22.85
MFRDC	58.57	105.00	0.00	33.34	32.21	34.47
MFRSKL	10.61	105.00	0.00	10.10	8.22	11.99
MAGKUS	102.73	105.00	0.00	12.44	12.20	12.68
MAGTUP	113.71	105.00	0.00	30.31	29.78	30.84
MRGEPOL	32.64	105.00	0.00	20.30	19.06	21.53

Table 5. T-test values basic motor experimental group

Variables	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
MTAP	77.09	105.00	0.00	29.15	28.40	29.90
MTAPN	70.85	105.00	0.00	24.67	23.98	25.36
MTAPNZ	62.83	105.00	0.00	20.44	19.80	21.09
MFLISK	37.49	105.00	0.00	68.98	65.33	72.63
MBFDS	30.40	105.00	0.00	20.34	19.01	21.67
MPD	45.00	105.00	0.00	44.16	42.21	46.11
MFESDM	64.77	105.00	0.00	153.92	149.20	158.63
MFESUM	50.88	105.00	0.00	28.10	27.01	29.20
MFE20V	81.40	105.00	0.00	4.25	4.14	4.35
MRCLDM	49.69	105.00	0.00	22.95	22.04	23.87
MFRDC	44.04	105.00	0.00	32.38	30.92	33.83
MFRSKL	12.36	105.00	0.00	13.42	11.27	15.58
MAGKUS	81.27	105.00	0.00	12.51	12.20	12.81
MAGTUP	83.50	105.00	0.00	31.05	30.31	31.79
MRGEPOL	33.27	105.00	0.00	20.28	19.07	21.48

MBFDS, MPD, MFESDM, MFESUM, MRCLDM, MFRDC and MFRSKL. On the long run, there has been a significant decrease in the values of variables MFLISK, MFE20V, MAGKUS, MAGTUP and MRGEPOL. As you can see the pattern of changes in values on the basic motor variables is the same as in the control group. However, significant changes indicate a significant effect of the work program on the values of all measured basic motor components in the experimental group.

Discussion

In the conducted research, anthropometric measures and motor abilities were assessed on a sample of 47 third-grade students who are engaged in additional physical activity or training in basketball in the section of the school sports society and who participate only in the regular teaching of physical and health culture. The results showed that students exercising additional physical exercise have significantly better results in motor skills, as well as a noticeable increase in muscle mass. The results of the t-test in the area of motor abilities show significant differences that occur in variables for estimating explosive (MSD), repetitive (MPT), and static power (MIV) for the benefit of students who exercise physically. Similarly, statistically significant differences were found in the flexibility assessment (MPR) and the simple movement rate (MTR) variable. A statistically significant difference was not found in the Coordinating Assessment Variable

(MPN), although there is a numerical difference in the results of the polygon backlash test for the benefit of additional physical activity students [16].

The results of the research Badrić et al., [17] show that after the training process lasting 8 weeks, statistically significant changes in the motor skills of the girls who were engaged in additional extracurricular activities in the school sports society were created. Similar results were obtained in their research [18, 19, 20, 21]. Girls progressed most in tests to assess explosive power and flexibility, but also significantly reduced agility performance. The results of this study show that significant differences appear in these abilities, while the differences in the coordination area are minimal. Additional physical activity within the work of a school sports society significantly influences the increase in the level of motor skills. Some previous research has found that transformational changes in motor skills are emerging in older girls who attend primary school. This research has shown obvious differences with nine-year-old girls. The results of the research Nićin, [22] and Petković, [23] show that additional physical activity increases the positive effects of both physical development and basic-motor abilities. From the obtained results, it is concluded that for more substantial transformations in the motor space, additional content is needed outside the teaching, assuming that the transformation of basic motor skills is greater when the higher level of motor knowledge is higher. The results show that additional involvement in kinesiological activity, and in this case it is basketball, with the regular teaching that forms the basis of all organizational forms of work in this area, ensures significant transformational effects. This affirms the value of sports in its best form, which is preparation.

Kinesiological contents are also shown here as a powerful generator of human adaptability as a self-improvement system. In this case, this is a school sport, which, considering the trends in the reduction of the standard of citizens, must be counted. School sport is the only choice for a large part of the population, and society should take responsibility for making exercise available to every child regardless of the material status of parents [17]. In his research: "A discriminatory analysis of the motor and functional abilities of sports-active and inactive students", on a sample of 64 students, divided into two sub-assemblies (sportively active and inactive students), the author established the existence of a difference between two sub-classes. The results of the study show that sports active students are better in tests for estimating explosive power, segmental velocity, vital lung capacity, and systolic and diastolic blood pressure [12]. In his doctoral dissertation: "Transformational processes of motor skills and anthropological characteristics under the influence of a seven-month treatment for third-and fourth-graders" on a sample of 206, divided into two subunits (experimental and control), a standard and experimental treatment of seven months. The results showed that three-hour experimental treatment performed by professors of physical education showed better results than the standard physical education program conducted by class teachers [6]. In his research: "The influence of programmed physical education on changes in motor skills in one-year students", the results of 70 hours of physical and health education in one year led to changes in all tested motor skills. Variables were the capabilities included in the tests of the Eurofit battery test [7].

On a sample of 110 pupils (boys and girls) 11 - 13 years, statistically significant changes were found in the structural process of motor dimensions of initial and final measurement, under the influence of the curriculum. A discriminatory analysis was done with the aim of defining quantitative changes that took place at two time points. Indicates that variables for balance estimation (flamingo), long jump (explosive power), tracking force (repetitive power of the hull), then the variable 10x5 have significantly changed significantly. The author also concludes that both boys and girls have the capacity to balance at both ages [8]. In his research: "The Effects of Programed Teaching on Improving Motor Skills in the Young Scholar Students" found that the programmed three-hour instruction for a week and seven months caused positive effects on improving motor skills, which were included in the testing [10]. In his paper: "The Impact of Experimental Treatment on Some Motor Abilities of Fourth-Grader Students", on a sample of 104 students, using the treatment resulted in a change in motor skills in tests for estimating the segmental velocity of the limbs, explosive forces. The Chinese treatment did not cause changes in the flexibility and static strength variables, which are influenced by the longitudinal dimensionality of the skeleton, that is, the static strength test is too heavy for the selected sample [14]. In the study of the change of biomotor pupils aged 11 years under the influence of the experimental program of sports games in relation to the standard physical education program, the sample was composed of 252 male students, which were divided into a control group and experimental group. A system of 33 variables (12 morphological and 21 for estimation of motor and functional abilities) was used. The experimental program was saturated with the contents of sports games. The results indicate that the morphological system contributes to the equal differentiation of the group, while the experimental group showed better results in the motor space, of which 14 variables showed a statistically significant difference in 13 variables. The experimental group was better [15]. In a study conducted on 153 subjects, 48 respondents participated in regular physical education with 2 hours of instruction. This was the first experimental group - E1. 56 subjects participated in regular physical education with 2 classes, plus the third extra hour per week. This was second experimental group - E2, with which professors of physical and health culture worked. The rest of 49 respondents participated in regular physical education classes with class teachers, with 2 lessons per week (control group - K). There were statistically significant changes in motor abilities in the final relative to the initial measurement in experimental groups relative to the control. On the basis of the obtained results it can be assumed that the proper methodological formulation of teaching work (physical exercise, load, methods for the development of certain abilities forms and forms of work, etc.) has had positive effects on motor skills when it comes to girls of third grade primary school [24].

This research was conducted with the aim of determining the effects of regular and modified physical education with the application of content from sports games (basketball, volleyball and handball) in the duration of one semester to changes in basic motor skills in primary school students in the fifth grade. The sample of respondents included 106 pupils in the V class, aged 10 to 11 years, clinically and mentally healthy, and with no pronounced morphological and locomotor impairments. The sample of respondents was divided into two subgroups, an experimental group (53 pupils), who carried out physical education classes according to the modified plan and program of sports games (basketball, volleyball and handball) for a semester and a control group (53 pupils) who attended regular classes from physical education according to the current curriculum. The variables used in this study consisted of 15 motor variables and variables for estimating the frequency of the movement (Tapping Hand - MTAP; Tapping Leg - MTAPN; Tapping Legs on the Wall - MTAPNZ); variables for assessing flexibility (stick turn - MFLISK; MFESDM; MFESUM; High Jump 20m - MFE2OV), variables for the estimation of the repetitive power (Test (MBFDS; laying-seat - MRCLDM; 40 seconds squash test - MFRDC; Push-ups - MFRSKL) and variables for assessing coordination (Steps aside - MAGKUS; Magnetic Test - MAGTUP; Polygon backwards - MRGEPOL). Descriptive statistics and T-test were used to determine changes in basic motor skills. The results of the research at the descriptive level showed noticeable differences between the same groups in the final versus the initial measurements. Based on the results of the t-test for the control and experimental group, it can be concluded that there have been statistically significant changes in values on all variants of basic motor in the final compared to the initial measurement. Thus, after the program of work in the experimental group there was significant increase of values on the variables MTAP, MTAPN, MTPNZ, MBFDS, MPD, MFESDM, MFESUM, MRCLDM, MFRDC and MFRSKL. On the long run, there has been a significant decrease in the values of variables MFLISK, MFE20V, MAGKUS, MAGTUP and MRGEPOL. Changes in the values of the basic motor variables are the same as for the control group. However, significant changes indicate a significant effect of the work program on the values of all measured basic engine components in the experimental group. By analyzing the results of the t-tests, it can be seen that the groups differ in the initial measurement only in one basic motor variant, MTAPN, and this difference is statistically significant in favor of the control group. In the final measurement, there are no significant differences between the control and the experimental group in the average values of all variants of basic motoring.

Conclusion

The results of this study have shown that the application of any physical education program can lead to changes in basic motor abilities in the final versus the initial measurement, regardless of the time period, if the lesson is performed. In order for the differences between the control and the experimental group to be greater and statistically significant, it is necessary to increase the weekly number of hours of physical education compared to the existing one or to include pupils in additional physical activity. The lifestyle of today's students is mainly reduced to sitting in school and at home with a computer, tablet or phone, IT workshops, music schools and foreign language schools. Therefore, students continue to sit in a sitting position with minimal movement after classes. This way of life, such poor and fast food, leads to the students' abilities becoming more and more lagging behind their physical development.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Dodig M. *Development of physical abilities of the human organism.* Rijeka: University of Rijeka; 1998.
2. Milanović D. *Basics of training theory, manual for sports trainers.* Zagreb: Faculty of physical culture; 1997.
3. Rađo I. *Transformation processes of motor and functional abilities and various aspects of swimming.* Sarajevo: FFK University of Sarajevo; 1997.
4. Drabik J. *Children and sports training.* Stadion publishing company; 1996.
5. Nikšić E, Rašidagić F, Mahmutović I, Mujčić A. *Ball games in the function of the development of a child.* Sarajevo: Faculty of educational sciences, University of Sarajevo; 2015.
6. Skender N. *Transformational processes of motor skills and anthropological characteristics under the influence of a seven-month treatment for students of the third and fourth grade.* [Graduate thesis]. Sarajevo: Faculty of sports and physical education; 2004.
7. Stanković A, Hadžikadunić M. The influence of programmed physical education on changes in motor skills in students of age 11. *NTS Collection of scientific works.* Sarajevo: FASTO; 2005.
8. Kučuk M. *Structural changes in morphological dimensions and motor skills of girls and boys.* [Master's thesis]. Tuzla: Faculty of physical education and sports; 2006.
9. Lakota R. *Effects of programmed work on transformation of basic-motor and situational-motor skills of handball players.* [Master's thesis]. Sarajevo: Faculty of sports and physical education; 2006.
10. Skender N. Effects of programmed classes on improving motor skills in pupils of younger age groups. In: *NTS Collection of scientific works.* Sarajevo: FASTO; 2007. P. 268-373,
11. Hadžikadunić A. *Transformation processes of basic motor, situational motor and functional abilities of pupils of the 8th grade under the influence of programmed teaching of physical and health education.* [Master's thesis]. Sarajevo:

Faculty of sports and physical education; 2007.
12. Batričević D. Discriminatory analysis of the motor and functional abilities between sports active and inactive pupils. *Sport science.*2008; 1(1): 50-53.
13. Mladenović M. The structural changes in sports games during physical and health education classes. *Sport science.* 2008; 1(2):39-43.
14. Nikolić I, Bokor I, Brerslauer I. The influence of experimental treatment on some motor skills of students of the fourth grade. In: *Collection of papers: 17*. Summer School of Kinesiology of the Republic of Croatia; 2008. P. 154-157.
15. Malacko J, Pejić A. Changes in the biomotor dimensions of pupils aged 11 years, the experimental program of sports games in relation to the standard program of physical education. *Sport science.* 2009; 2(1): 52-61.
16. Gašparić Z. *The influence of additional physical activity on the development of motor skills of students.* [BSc thesis]. Petrinja: University of Zagreb, Teacher's faculty, Department of Teacher Studies; 2015.
17. Badrić M, Prskalo I, Sporiš G. Effects of Programmed Training on the Motor Skills of Female Basketball Players in School Sports Societies. *Croatian Journal of Education.* 2015; 17(1): 71-81. https://doi.org/10.15516/cje.v17i0.1516
18. Kilinç F. An intensive combined training program modulates physical, physiological, biomotoric, and technical parameters in women basketball players. *J Strength Cond Res.* 2008; 22(6): 1769-78. https://doi.org/10.1519/JSC.0b013e3181854bca
19. Zuccolo. The influence of six-month training on changes in some variables of basic motor skills in young basketball players. In: Findak V. (Ed.*) Collection of works, 16th Summer School of Kinesiologists of the Republic of Croatia Anthropological, methodical, methodological and professional assumptions of work in the fields of education, sports, sports recreation and kinesitherapy.* Zagreb: Croatian Kinesiological Association; 2007. P. 274-282.
20. Milanović D, Jukić I, Itoudis D. The influence of programmed training on changes in the motor skills of young basketball players. *Kinesiology.* 1994; 26(1-2): 3343.
21. Blašković M, Matković B, Matković BR. The influence of physical activity on the development of some basic motor abilities in boys. *Kinesiology.* 1993; 25(1-2): 33-38.
22. Nićin Đ. *Anthropomotorika*. Novi Sad: Faculty of physical culture; 2000. [In Serbian]
23. Petković J. Differences in the connection of motor skills with success in the realization of program contents of sports gymnastics in relation to the age of the respondents. *Sport Mont.* 2007; 12,13,14 (5), 489-492.
24. Džibrić Dž., Pojskić H, Ferhatbegović A, Ganić E, Hasanbegović S, Terzić A. The effects of teaching physical and health culture on the basic and motor skills of students. *Collection of papers of the 20th summer school of kinesiologists of the Republic of Croatia, Croatian Kinesiological Association*. Poreč, June; 2011. P. 239-246.

Information about the authors:

Nikšić E.; (Corresponding author); http://orcid.org/0000-0002-1849-9693; elvira.beganovic1982@gmail.com; Faculty of Education Science, University of Sarajevo; 71000 Sarajevo, Bosnia and Herzegovina.

Beganović E.; http://orcid.org/0000-0002-5190-6035; edinn.beganovic@hotmail.com; Faculty of Physical Education and Sport, University of Sarajevo; 71000 Sarajevo, Bosnia and Herzegovina.

Rašidagić F.; http://orcid.org/0000-0002-1153-5719; faris.rasidagic@gmail.com; Faculty of Physical Education and Sport, University of Sarajevo; 71000 Sarajevo, Bosnia and Herzegovina.

Mirvić E.; http://orcid.org/0000-0003-0537-117X; edinmirvic@gmail.com; Faculty of Physical Education and Sport, University of Sarajevo; 71000 Sarajevo, Bosnia and Herzegovina.

Joksimović M.; http://orcid.org/0000-0003-4232-5033; nicifor007@outlook.com; Faculty of Physical Education and Sport, University of East Sarajevo; 71420, Pale, Bosnia and Herzegovina.

Cite this article as:
Nikšić E, Beganović E, Rašidagić F, Mirvić E, Joksimović M. The effects of physical education on changes of basic motor skills of female students in the fifth grade of elementary school. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):296-305.
https://doi.org/10.15561/18189172.2019.0604

Received: 25.08.2019
Accepted: 27.09.2019; Published: 30.09.2019

PSYCHOLOGY medical-biological problems of physical training and sports

Investigation of the effect of supramaximal eccentric contractions on muscle damage and recovery between the dominant and non-dominant arm

Yapıcı A.[1ABCDE], Yalçın H.B.[2ABCD]

[1]School of Physical Education and Sports, Hatay Mustafa Kemal University, Turkey

[2] Faculty of Physical Education and Sports, Bolu Abant İzzet Baysal University, Turkey

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: This research aimed to examine the effects of supramaximal eccentric contractions on the damage of muscle and recovery between the dominant and non-dominant arm. The study was participated by ten male volunteer students who do not have any musculoskeletal and metabolic compliant. This research designed as a cross-over type research.

Material: Venous blood samples were drawn before the bout, immediately after the bout one min., moreover, at the 6th, 24th, 48th, and 72nd hours after training. Data were analyzed using the SPSS 21.0 statistical software package. After exercise, the non-parametric Wilcoxon Signed Ranks Test was used to decide the dominant and non-dominant arm influence. Statistical significance for all analyses was accepted at $p< 0,05$.

Results: There was a significant statistical difference in the right, and left arm Creatine Kinase (CK) values at the time when exercise start, 48th and 72nd hours ($p<0,05$). There was no statistically significant difference in right and left arm Lactate Dehydrogenase values after exercise ($p>0,05$).

Conclusions: There was an increase in muscle damage at 24th and 48th hours after supramaximal eccentric exercise, and it was turned back the start level at 72nd hours. While the arm which is non-dominant recovery is faster than the dominant arm.

Keywords: eccentric contraction, recovery, muscle damage, creatine kinase, lactate dehydrogenase.

Introduction

According to Hollmann [1], muscle strength that is confronted with resistance may contract or withstand a specific endurance and according to Nett [2], the ability of a muscle to resist a resistance by tension and relaxation. There are many different methods in order to improve muscle strength. That feature is improved with changing both training methods and contraction types [3]. Soft tissue injuries due to sprains and bumps are common. Those injuries can be treated with rehabilitation implications. In addition to the soft tissue injuries, cellular damage also occurs during the exercise. This situation mainly described *as microtrauma* or *microinjury* or *muscle damage* [4, 5]. Intensity and form of the exercise cause different levels of muscle damage [6].

Skeletal muscle damage occurs after a high-intensity or unusual type of exercise, and this type of muscle damage is a widespread physiological condition and can occur even in the activities needed in our daily life. Three types of muscle damage symptoms are known in long-term exercises, ongoing or intermittent forced contractions. The most common of these is known as delayed-onset muscle soreness (DOMS), and as a result, people complain of weakness, fatigue and tenderness in the muscle that starts 12-48 hours after exercise [7, 8].

Increased blood levels of some muscle enzymes involved in circulation as a result of deterioration of muscle membrane are biochemical symptoms indicating muscle damage and degree. The intracellular localization of enzymes is essential in determining the degree of cell damage. The enzyme that only shows activity in a particular tissue or has much higher activity in a particular tissue is called the dominant enzyme. Increased serum activity of such an enzyme indicates damaged tissue. Determination of the total amount of damage caused in the muscle is challenging since the exercise response is at different levels in different muscle and muscle fibers, the different muscles contain enzyme and protein markers at different concentrations, and the damage is not homogeneously distributed in the muscle [9, 10].

Increased levels of some enzymes cause severe muscle tissue damage in large muscle tears. Skeletal muscle damage causes muscle-specific components to leak from the membrane into the bloodstream. Structures used in studies to detect skeletal and cardiac muscle damage; usually examine creatine kinase (CK) and its lower isoforms, myoglobin, aspartate aminotransferase (AST), lactate dehydrogenase (LDH), brain natriuretic peptide (BNP), atrial natriuretic peptide (ANP), carbonic anhydrase, troponin, and muscle-building proteins [11, 12]. The most important and most used of these structures is CK [13, 14].

CK is an enzyme found in high density in the heart, skeletal muscle, and brain tissue. CK in the brain content rarely crosses the blood-brain barrier and circulates. There are three isoenzymes called MM, MB, BB. MM (CK3) found in skeletal and heart muscle, BB (CK1) in the brain, MB (CK2) in the heart muscle. The source

doi:10.15561/18189172.2019.0605

of CK levels measured in circulation is predominantly skeletal or cardiac muscle. Skeletal or cardiac muscle trauma or necrosis increases the circulatory level of this enzyme [15]. Therefore, at high CK levels, skeletal, or cardiac muscle damage should be sought first [16, 17]. According to Kaplan and Pesce [17], average CK values are between 95-140 U / L. CK's upper reference values are twice as high in athletes as in non-athletes. Schumann and Klauke [18], set these limits at 391-398 U / L for men; In women, between 240-207 U / L.

LDH is an enzyme that is found in many tissues and passes into serum if these tissues are damaged. The determination of isoenzymes can demonstrate the tissue from which LDH originates. When operated at 37 ° C, normal values are 210-420 U / L [19, 20].

LDH shock and circulatory failure, hypoxia, heart failure, excessive hyperthermia, acute myocardial infarction, cholestasis, primary tumors of the liver, megaloblastic and pernicious anemia, hemolytic anemia, lung diseases, increases in cases of muscle diseases. Increases in skeletal muscle trauma, inflammatory or degenerative muscle diseases. There are five isoenzymes in the circulation, called LDH-1, 2, 3, 4 and 5. Total LDH activity increases in many tissue and organ diseases due to the widespread tissue distribution of isoenzymes. Therefore, an additional examination is required for differential diagnosis [20, 21].

Muscle damage caused by eccentric exercise can be assessed by direct methods such as muscle biopsy or magnetic imaging, or indirectly by markers such as decreased muscle strength, edema, pain, increased serum levels of muscle enzymes and some markers of inflammation. Direct methods are often not preferred due to several difficulties in practice, but it is seen that changes in muscle strength and serum enzymes are mostly used in the assessment of eccentric muscle damage [22, 23].

Clarkson et al. [24], showed that very intensive eccentric exercise leads to an adaptation that causes less damage when repeated in the same way after a few weeks. It is not known precisely when and how this adaptation occurred. However, it was found that a person who repeated an exercise within five days showed an adaptation response. After five days of exercise, people experienced mild pain despite improvement and reduced loss of strength and range of motion. Thus, although the muscle is not fully restored, a specific adaptation has occurred [25].

In their study, Nosaka et al. [26] made the same high-intensity exercise twice in the two groups, the first group did the exercises every six weeks, and the other group performed ten weeks apart. As a result, they found that isometric strength loss, arm flexion at full flexion and muscle pain were significantly lower in the group who exercised at six weeks interval compared to the first application in the second application. In the exercise group after ten weeks, it was found that there were significantly lower answers in the rest arm angle compared to the first in the second application. However, there were similarities between the first and second applications in terms of muscle pain level, arm angle at full flexion, and isometric strength loss.

In terms of CK, there was almost no increase in both groups after the second application. When a small sample of these subjects performed exercise after six months, CK response was still low, and all other measurements were close to the values at the first application. Accordingly, adaptation, strength recovery, muscle shortening state (closed-arm angle) and muscle pain for six weeks, sudden muscle contraction (open arm angle) takes about ten weeks and six months for CK response [24].

After the eccentric exercise, a certain period is required to return the markers of damage to the muscle [27]. Clancy and Clarkson [28], suggest that 3-day immobilization after damage-induced eccentric exercise improves isometric force recovery but has no effect on other muscle functions. Lehto et al. [29], muscle regeneration was accelerated by 5-day immobilization and return to regular movements after the damage caused in the muscle.

Materials and Methods

Participants

This research has aimed the examine the effects of supramaximal eccentric contractions on the damage of muscle and recovery between dominant and non-dominant arm. The study consists of 13 male volunteers active in sports. It was determined that three subjects exercised outside the practice while the study was in progress, and they were excluded from the study. The research was carried out based on the cross-tab test model. Before work begins, an ethical report was taken from Abant Izzet Baysal University Clinical Research Ethics Committee.

Table 1. Demographic characteristics of the research group.

Variables	N	Minimum	Maximum	x̄	S.D.
Age	10	22	26	23,3	1,3
Height	10	170	192	178,9	7,09
Weight	10	60	100	78,2	13,8

According to Table 1, the mean age of the study was 23.3 ± 1.3 years, the mean height was 178.9 ± 7.09 cm, and the mean body weight was 78.2 ± 13.8 kg, who do not have any musculoskeletal and metabolic compliant ten male volunteer students participated. It was determined by asking themselves whether they use any ergogenic adjuvant and regular medication for health problems and their dominant arms. All subjects indicated that they used dominant right arms.

An information meeting was held with the students who wanted to participate in the research, and the subjects were informed about the study by giving pre-experiment information form and test protocol. The subjects were asked to read and sign the form indicating that they were volunteer, and their body weights were carried out in standard clothing (shorts and t-shirts), without shoes, electronic scales in the upright position, height measurements were made with height meter and biceps circumference measurements for both arms with a tape measure. Then the groups were determined by a random method.

The exercise protocol was held between 16:00-17:00. One week before the study, the maximal weights of the subjects were determined by one-rep maximum (1 RM) method. In order to eliminate the differences that may arise from experience, cross-tab pattern was applied. One group performed the exercise with the dominant arm and the other group with the non-dominant arm. Then the groups changed places.

Exercise Protocol

Before starting the study, venous blood samples of the subjects were taken from the antecubital vein in a resting and sitting manner by the health personnel. Five of the subjects then performed the eccentric phase of the biceps lifting movement with their supramaximal weights with the right arm and the other five with their left arms. The subjects had a passive role in the concentric phase, and the person conducting the study performed that phase. The study was continued until the person was unable to continue the exercise, and the subject was completed by disrupting the rhythm or voluntarily terminating the study. The health personnel took venous blood samples at the first minute, 6th, 24th, 48th, and 72nd hours following the end of the study. Six days after the blood was drawn at 72 h, subjects performed the study with their other arms, and the blood collection procedure was re-administered as in the first stage.

Statistical Analysis

The data obtained from the study were analyzed in SPSS 21.0 package program. The Wilcoxon Signed Ranks Test was used to determine the interaction of Creatine Kinase (CK) and Lactate Dehydrogenase (LDH) in the dominant and non-dominant arms at the first minute, 6, 24, 48 and 72 hours after exercise. Bonferroni correction was used to show a statistical difference. The results were evaluated at $p < 0.05$ significance level.

Results

According to Table 2, the mean training age of the group was 9.6 ± 2 years, the average training frequency was 3.6 ± 0.6 days, the average total training time was 6.7 ± 2.1 hours, the D arm maximal force average 20.5 ± 4.6 kg, the ND arm maximal strength 20.2 ± 4.7 kg detected it was.

In Table 3, D and ND arm CK enzyme values of the first minute, 6, 24, 48 and 72nd hours following the exercise were analyzed comparatively and the first minute, 6, 24 and 72nd hours were statistically analyzed. There was no significant difference ($p > 0.05$). A statistically significant difference was found in the 48th-hour values after exercise (Z: -2.191; $p < 0.05$).

According to Table 4, There was no significant difference the pre-exercise (resting) value was compared with the D arm CK enzyme activities at the first minute, 6 and 72nd hours ($p > 0.05$). A statistically significant difference was found in the 24 and 48th hours values ($p < 0.05$).

According to Table 5, pre-exercise (resting) values were analyzed by comparing the CK enzyme activities of the ND arm at the first minute, 6, 24, 48, and 72nd hours after the exercise. There was no statistically significant difference at the first minute, 48 and 72nd hours values ($p > 0.05$). A statistically significant difference was found in the 6 and 24th hours values ($p < 0.05$).

Table 6, 6, 24, 48 and 72nd hours after exercise D and ND arm LDH enzyme values were analyzed; comparatively, LDH enzyme recovery phase comparison

Table 2. Physiological characteristics of the research group (D:Dominant-ND: Non-Dominant)

Variables	N	Minimum	Maximum	x̄	S.D.
Training age	10	6	12	9,6	2,0
Training frequency	10	3	5	3,6	0,6
Total training time	10	3	10	6,7	2,1
D max. force	10	12,5	30	20,5	4,6
ND max. force	10	12,5	30	20,2	4,7

Table 3. Compared to the D and ND CK enzyme statistical analysis values

Variables	CkND 0. m – CkD 0. m	CkND 6. h – CkD 6. h	CkND 24. h – CkD 24. h	CkND 48. h – CkD 48. h	CkND 72. h – CkD 72. h
Z	-0,561	-1,172	-1,478	-2,191	-1,581
Significance	0,575	0,241	0,139	0,028	0,114

Table 4. Resting and D compared CK enzyme statistical analysis values

Variables	Ck rest – Ck D 0. m	Ck rest – Ck D 6. h	Ck rest – Ck D 24. h	Ck rest – CkD 48. h	Ck rest – Ck D 72. h
Z	-0,969	-1,172	-1,836	-1,784	-1,275
Significance	0,333	0,241	0,014	0,041	0,202

Table 5. Resting and ND compared CK enzyme statistical analysis values

Variables	Ck rest – Ck ND 0. m	Ck rest – Ck ND 6. h	Ck rest – Ck ND 24. h	Ck rest – Ck ND 48. h	Ck rest – Ck ND 72. h
Z	-1,784	-2,293	-1,988	-1,886	-1,478
Significance	0,074	0,022	0,047	0,059	0,139

Table 6. D and ND compared LDH enzyme statistical analysis values

Variables	Ldh ND 0. m – Ldh D 0. m	Ldh ND 6. h – Ldh D 6. h	Ldh ND 24. h – Ldh D 24. h	Ldh ND 48. h – Ldh D 48. h	Ldh ND 72. h – Ldh D 72. h
Z	-1,482	-1,008	-0,765	-0,510	-0,510
Significance	0,138	0,314	0,444	0,610	0,610

Table 7. Resting and D compared LDH enzyme statistical analysis values

Variables	Ldh rest – Ldh D 0. m	Ldh rest – Ldh D 6. h	Ldh rest – Ldh D 24. h	Ldh rest – Ldh D 48. h	Ldh rest – Ldh D 72. h
Z	-0,663	-1,173	-2,191	-2,701	-1,224
Significance	0,507	0,241	0,028	0,007	0,221

Table 8. Resting and ND arm compared LDH enzyme statistical analysis values

Variables	Ldh rest – Ldh ND 0. m	Ldh rest – Ldh ND 6. h	Ldh rest – Ldh ND 24. h	Ldh rest – Ldh ND 48. h	Ldh rest – Ldh ND 72. h
Z	-1,376	-1,988	-2,244	-2,497	-1,580
Significance	0,169	0,047	0,025	0,013	0,114

values were not a statistically significant difference (p> 0.05).

According to Table 7, LDH enzyme activities were analyzed by comparing the pre-exercise (resting) value with the D arm at the first minute, 6, 24, 48, and 72nd hours after the exercise. There was no statistically significant difference at the first minute, 6 and 72nd hours values (p>0,05). A statistically significant difference was found in the 24 and 48th-hour values (p <0.05).

According to Table 8, pre-exercise (resting) values were analyzed by comparing to ND LDH enzyme activities at the first minute, 6, 24, 48, and 72nd hours after the exercise. There was no statistically significant difference between at the first minute and 72nd hours values (p> 0.05). A statistically significant difference was found in the 6, 24, and 48th-hour values (p <0.05).

Discussion

Statistically significant differences were found in ND arm CK, D arm CK, and D arm LDH enzymes. There was no statistically significant difference in ND arm LDH enzyme. These results prove that recovery in both arms occurred at 72nd hours. According to the values of CK and LDH, at the first minutes, 24, 48 and 72nd hours, there was a statistically significant difference in D and ND arm values of both enzymes. As can be seen from these results, different reactions occurred in both enzymes in the D and ND arm.

There was no statistically significant difference between the D and ND arm CK enzymes at the first minute, 6, 24, and 72nd hours after the exercise. A statistically significant difference was found in the 48th-hour values after exercise. According to these results, similar effects were observed in both arms after exercise, and at 48th hour the arms showed different reactions. In other words, muscle damage increased up to 48th hour reached its highest level at 48th hour, and recovery was achieved towards 72nd hours.

There was no statistically significant difference between D and ND arm CK enzyme activities and D arm at the first minute, 6 and 72nd hours after the exercise. A statistically significant difference was found in the 24 and 48th-hour values. There was no statistically significant difference in ND arm values at the first minute, 48 and 72nd hours, and a statistically significant difference was found in the 6th and 24th-hour values. Again, these results indicate that muscle damage reached the highest level at 24 and 48th hours, and returned to pre-exercise (resting) state around 72th hour. The results indicated that CK enzyme values at the first minute, 6 and 72nd hours of the D arm were similar to resting values, whereas 24 and 48th-hour values were different from resting values. In the ND arm, the values of the first minute, 48 and 72nd hours are similar to rest values, and the values of 6 and

24th hours differ from rest values. Based on these results, recovery was observed in both arms, and recovery was faster in the ND arm compared to the D arm.

LDH enzyme activities of the D arm at the first minute, 6, 24, 48 and 72nd hours after the exercise were rested and no statistically significant difference was found in the first minute, 6, 72th hours. A statistically significant difference was found in the 24 and 48th-hour values. There was no statistically significant difference in ND arm values between rest and first minute and 72nd hours. A statistically significant difference was found in the values of 6, 24, and 48th hours. According to these results, it was seen that the LDH enzyme reached the highest level in both arms at 24 and 48th hours and recovery occurred in similar periods.

The results of the study conducted by Hazar et al., [30] strength training after the study of the relationship between muscle pain and muscle damage with their study, Jubeau et al., [31] voluntary and stimulating contractions of muscle strength, growth hormone (GH), blood lactate and muscle damage is aimed to compare changes with voluntary and stimulated leg press exercise serum growth hormone concentration, blood lactate, isometric maximal voluntary contraction strength (MVC), serum creatine kinase (CK) activity and muscle pain were similar in terms of recovery time.

In addition, in terms of recovery time of creatine kinase (CK) enzyme results of the study, Nosaka and Clarkson, [32] maximal isometric power, elbow angle, muscle pain and cretin kinase levels are aimed to determine the eccentric phase of elbow flexion movement, Jamurtas et al., [33] of a similar intensity of eccentric muscle injury in the leg and arm after the exercise aimed to compare submaximal workload eccentric knee extension and elbow flexion movement they have done and Bruunsgaard et al., [34] increased cytokine level after exercise and muscle damage is similar to the work done to determine the intended muscle damage.

Conclusions

As a result, muscle damage after supramaximal eccentric exercise increased at 24 and 48th hours and returned to baseline at 72nd hours. A statistically significant difference in the 48 and 72nd-hour values is an indication of this situation. Although similar results were observed, the non-dominant arm recovered faster than the dominant arm. CK enzyme, the right arm values, the left arm values are a statistically significant difference is an indicator of this situation. This can be attributed to the lower performance of the subjects with non-dominant arms.

The results of this study will help athletes, coaches, or researchers to know what changes are happening to the human body after an exercise involving eccentric contractions with the supramaximal workload. Also, this study will help to prepare the training units, and recovery periods will be more comfortable to determine when the recovery time is fully known.

Suggestions for the future studies

- In addition to this study, different enzyme activities, which are markers of muscle damage, can be examined.
- Muscle damage can be examined by taking a muscle sample (biopsy).
- Muscle damage and changes in recovery time can be examined by taking blood samples at different times.

Suggestions for researchers

- Based on the results of this study, researchers may investigate the rate of muscle damage removal by taking some dietary supplements that are known to help recovery during rest.
- Investigate contraction types and interactions with different contraction exercises for different extremities (dominant or non-dominant).

Conflict of interests

The authors declare that there is no conflict of interests.

References

1. Holmann W. *Sport-Medicine.* Berlin: Springer Verlag, 1972.
2. Nett T. *Leichtathletiches muskel training* [Track and field muscle training]. Berlin: Verlag Bartels und Wernitz K. G., 1970. (In German)
3. Şen İ. Effect of carbohydrate-protein (Cho-p) supplement on attenuation of muscle damage induced by eccentric exercise in Turkish ski racers. *Turkish J Phys Med Rehab,* 2011;57:14-18.
4. Erdoğan M. *Farklı ısı koşullarında uygulanan maksimal aerobik yüklenmenin kas hasarı ve performans üzerine etkileri* [The effect of the different heat conditions after maximal endurance exercise on muscle damage and performance]. Ankara: Gazi University Press; 2009. (In Turkish)
5. Hazar S. *Farklı türdeki kuvvet antrenmanlarının iskelet ve kalp kası enzim aktivitelerine akut etkisi* [Accute effect of various strength training on skeletal muscle enzyme activities and on myocard enzyme activities]. Ankara: Gazi University Press; 2004. (In Turkish)
6. Akyüz M. *Müsabaka süresince erkek futbolcularda oluşan kas hasarı* [The muscle damage occured on young male fotball players during match]. Ankara: Gazi University Press; 2007. (In Turkish)
7. Christopher T, Daley W. In: Bull R, Charles O R, William O R. *Bull's handbook of sports injuries*. 2nd ed., New York: Mc Graw Hill Publishing Company; 2004.
8. Ross M. Delayed-onset muscle soreness work out now, pay later? *The physician and sports medicine*, 1999; 27 (1): 9- 13. https://doi.org/10.3810/psm.1999.01.625
9. Murray RK, Gramer DK, Mayes PA, Rodwel VW. *Harper'in biyokimyası* [Harper's biochemistry]. 24th ed. İstnabul: Barış Kitabevi; 1998. (In Turkish)
10. Vasilis M. Reference intervals for serum creatine kinase in athletes. *Br J Sports Med,* 2007; 41: 674- 678. https://doi.org/10.1136/bjsm.2006.034041
11. Harbili S, Gencer E, Ersöz G, Demirel H A. Orta şiddetli ekzentrik egzersiz diğer hasar belirteçlerini etkilemeksizin plazma kreatin kinaz düzeyini arttırır [Moderate intensity

eccentric exercise results in increases in plasma ck level without effecting any other damage indicators]. *Selçuk Üniversitesi Bed Eğt ve Sp Bil Der*, 2008; 10 (1): 21-31. (In Turkish)

12. Güçlü G. *Yüzme ve koşu egzersizinin sıçan kas lifi tipleri üzerine etkisi* [The effect of swimming and treadmill exercises on muscle fiber type of rat]. Kayseri: Erciyes University Press; 2008. (In Turkish)
13. Smith L L, Miles M P. *Exercise-induced muscle injury and inflammation* In.: William E, Garret J R, Kirkendall D T. *Exercise and sport science*. Philadelphia: Lippincott Williams and Wilkins, 2000. P. 401-411.
14. Walsh B, Tonkonogi M, Malm C, Ekblom B, Sahlin K. Effect of eccentric exercise on muscle oxidative metabolism in humans. *Medicine and science in sports and exercise*, 2001; 33 (3): 436- 441. https://doi.org/10.1097/00005768-200103000-00016
15. Archana P, Lal AK, Negi KS. Serum creatine kinase activity in thyroid disorders. *J K Sci,* 2007; 9 (1): 25-26.
16. Günay M, Cicioğlu İ. *Spor fizyolojisi* [Sport physiology]. Ankara: Gazi Kitapevi; 2001. (In Turkish)
17. Kaplan LA, Pesce AJ. *Clinical chemistry*: *Theory, analysis, and correlation*. 3rd ed., St Louis: Mosby Publishing; 1996.
18. Schumann G, Klauke R. New IFCC reference procedures for the determination of catalytic activity concentrations of the five enzymes in serum: Preliminary upper reference limits obtained in hospitalized subjects. *Clin Chem Acta*, 2003; 327:69– 79. https://doi.org/10.1016/S0009-8981(02)00341-8
19. Vural S, Çetin E, Tuzlacı U. *Klinik teşhiste laboratuar* [Laboratory in clinical diagnosis]. İstanbul: Uycan Basım Sanayi; 1986. (In Turkish)
20. Bernard J H. *Clinical diagnosis and management by laboratory methods*. 20th ed., Philadelphia: W. B. Saunders Company; 2001.
21. Wallach J. *Interpretation of diagnostic tests*. 7th ed., Philadelphia: Lippincott Williams and Wilkins; 2000.
22. Harbili S. Egzersize bağlı kas hasarı. [Muscle injury due to exercise] *Atletizm bilim ve teknoloji dergisi*, 2004; 55: 13-18. (In Turkish)
23. Kasper CE, Talbot LA, Gaines JM. Skeletal muscle damage and recovery. *American association of critical nurse clinical*, 2002; 12 (2): 237- 247. https://doi.org/10.1097/00044067-200205000-00009
24. Clarkson PM, Nosaka K, Braun B. Muscle function after exercise-induced muscle damage and rapid adaptation. *Medicine and science in sports and exercise*, 1992; 24 (5): 512- 520. https://doi.org/10.1249/00005768-199205000-00004
25. Ebbeling CB, Clarkson PM. Exercise-induced muscle damage and adaptation. *Sports Med*, 1989; 7 (4): 207- 234. https://doi.org/10.2165/00007256-198907040-00001
26. Nosaka K, Clarkson PM, Mc Guiggin ME, Byrne JM. Time course of muscle adaptation after high force eccentric exercise. *Eur J Appl Physiol and Occupational Physiol*, 1991; 63 (1): 70- 76. https://doi.org/10.1007/BF00760804
27. Allen DG. Eccentric muscle damage: Mechanisms of early education of force. *Acta physiologica seandinamics*, 2001; 171 (3): 311- 319. https://doi.org/10.1046/j.1365-201x.2001.00833.x
28. Clancy SP, Clarkson PM. Immobilization during recovery from eccentric exercise-induced muscle damage. *Medicine and science in sports and exercise*, 1990; 22: 37. https://doi.org/10.1249/00005768-199004000-00220
29. Lehto M, Duance VC, Restall D. Collagen and fibronectin in a healing skeletal muscle injury. An immunohistological study of the effects of physical activity on the repair of injured gastrocnemius muscle in the rat. *J. Bone and Joint Surgery British Volume*, 1985; 67-B (5): 820- 828. https://doi.org/10.1302/0301-620X.67B5.3902851
30. Hazar S, Erol E, Gökdemir K. Kuvvet antrenmanı sonrası oluşan kas ağrısının kas hasarıyla ilişkisi [The relationship between the muscle damage and muscle sorenes after strength training]. *Gazi beden eğitimi ve spor bilimleri dergisi*, 2006; 11 (3): 49-58. (In Turkish)
31. Jubeau M, Sartorio A, Marinone PG, Agosti F, Van Hoecke J, Nosaka K, Maffiuletti NA. Sex differences in steroidogenesis in skeletal muscle following a single bout of exercise in rats. *J Appl Physiol*, 2008; 104 (1): 75- 81. https://doi.org/10.1152/japplphysiol.00335.2007
32. Nosaka K, Clarkson P M. Muscle damage following repeated bouts of high force eccentric exercise. *Medicine and science in sports and exercise*, 1995; 27 (9):1263- 1269. https://doi.org/10.1249/00005768-199509000-00005
33. Jamurtas AZ, Theocharis V, Tofas T, Tsiokanos A, Yfanti C, Paschalis V, Koutedakis Y, Nosaka K. Comparison between leg and arm eccentric exercises of the same relative ıntensity on indices of muscle damage. *Eur J Appl Physiol,* 2005; 95 (2): 179- 185. https://doi.org/10.1007/s00421-005-1345-0
34. Bruunsgaard H, Galbo H, Halkjaer-Kristensen J, Johansen TL, MacLean DA, Pedersen BK. Exercise-induced increase in serum interleukin-6 in humans is related to muscle damage. *Journal of physiology,* 1997; 499 (3): 833- 841. https://doi.org/10.1113/jphysiol.1997.sp021972

Information about the authors:

Yapıcı A.; (Corresponding author); http://orcid.org/0000-0002-9293-5772; ademyapici@mku.edu.tr; School of Physical Education and Sports, Hatay Mustafa Kemal University; Antakya, Hatay, Turkey.

Yalçın H.B.; http://orcid.org/0000-0001-5038-0759; yalcin_h@ibu.edu.tr; Faculty of Physical Education and Sports, Bolu Abant İzzet Baysal University; 14030 - Merkez / Bolu. Turkey.

Cite this article as:
Yapıcı A, Yalçın HB. Investigation of the effect of supramaximal eccentric contractions on muscle damage and recovery between the dominant and non-dominant arm. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):306-312.
https://doi.org/10.15561/18189172.2019.0605

Received: 05.08.2019
Accepted: 04.09.2019; Published: 30.09.2019

The psychophysiological differences between expert and novice rifle shooters during the aiming period

Yıldız M. [1ABCDE], Fidan U.[2ABCDE]

[1]*The School of Physical Education and Sports Teaching, Afyon Kocatepe University, Turkey*
[2] *Faculty of Engineering, Biomedical Engineering, Afyon Kocatepe University, Turkey*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Purpose: Determination of mental status of the rifle shooters during the shooting performance is critical for the development of mental training programs according to their skill levels. The purpose of this study was to investigate the psychophysiological differences of expert and novice rifle shooters.

Material: Fourteen expert (age: 28.08±9.12 years, height: 176.12±4.24 cm, weight: 73.56±5.28 kg) and twenty novice shooters (age: 21.08±3.12 years, height: 177.42±3.74 cm, and weight: 71.56±3.57 kg) participated in the current study. The participants performed five shootings from a distance of 10m. The averages of each shooter's five shooting scores, values of attention and meditation, and heart rate between 5-sec before shooting and shooting moment were obtained.

Results: It was determined that shooting scores (10.02 ±0.49 vs. 7.6±2.86, p<0.01, respectively) and meditation level (71.50±21.05 vs. 52.93±20.54, p<0.05, respectively) were significantly higher in the experts while attention level (73.63±21.11 vs. 59.76±21.26, p<0.05, respectively), and heart rate (105.34±12.12 vs. 98.67±7,12 bpm, p<0.05, respectively) were found higher in the novices.

Conclusions: The novices and experts present different psychophysiological responses during the aiming period. It is suggested that the psychophysiological differences can be useful to categorize shooters and to provide feedback in training because it is important to develop programs according to group levels, especially in the development of mental training programs. Besides, it is determined that the mobile EEG device is an effective method for determining the mental status of athletes in sports specific activities.

Keywords: rifle shooting, attention, meditation, novice, expert.

Introduction

Rifle shooting is an Olympic sport in which athletes shoot a fixed target at a distance of 10 meters. The athletes have to hit the target with 10 rings that are intertwined. The most successful shot is obtained by hitting the inner ring [1]. A successful shot depends on the rifle hold, aiming accuracy and trigger control [2, 3]. Therefore, it is necessary to use both motor skills and psychological factors in the shooting process [4].In the related literature, it is reported that postural balance is the most important motor skill in rifle shooting [5]. The smallest change in posture can lead to significant changes in the score. In this context, it can be said that high postural balance and minimal movement of the rifle barrel are important determinants of the shooting performance [4]. However, It is well known that elite athletes enhance a range of sport-specific cognitive skills as well as possessing motor skills [6, 7]. Lee reported that attention and meditation are the most important psychological factors that affect performance in rifle shooting because shooting performance is very comprehensive and it requires high intense of focusing [7]. When a shooter directs his rifle to the target, he must focus on many different points (target, sight, trigger and so on). Therefore, the shooter must separate himself from the outside world and concentrate on what he does [8]. However, air rifle competitions are psychologically stressful situations for shooters. It is well known that expectations regarding performance increase anxiety, heart rate and blood pressure in people [9]. Therefore, determination of the mental status of the athletes during the shooting performance of rifle shooters is critical for the development of mental training programs according to their skill levels. Berka et al. determined that when novices monitor their own learning progress effectively they can adopt and integrate advanced techniques in the learning process [10]. Moreover, elite athletes enhance a range of sport-specific cognitive skills [6, 7, 11]. Therefore, determining of psychophysiological differences of expert and novice athletes can be useful to categorize athletes according to group levels and to provide feedback in their mental status. Self-reports or visual assessment by an examiner are generally used to determine the mental status of athletes. However, these methods may not reliably and objectively reflect the mental status of athletes because of the implicit nature of motor learning [11].

For many years, Electroencephalography (EEG) method has been commonly used as a neurologic technique for determining psychophysiological measurements of athletes. In this application, the electrical potentials of the brain cells are recorded by the sensors placed on the head. In the EEG studies, it was found that the brain oscillation (alpha, beta, theta, and so on) was associated with specific frequency bands and mental states (calm, arousal, attention, and so on) [12]. In the EEG measurements, theta waves (4~7 Hz) are usually associated with early sleep while delta waves (0.1 ~ 3 Hz) are associated with deep sleep. Moreover, beta waves (13 ~ 30 Hz) are related with

doi:10.15561/18189172.2019.0606

mental focusing and active thought, while alpha waves (8 ~ 12 Hz) are related with relaxation or resting state [13].

The traditional EEG has to be conducted in well-controlled laboratory settings. Therefore, it is impossible measuring the mental status of athletes when performing sport specific tasks in the real world. Moreover, laboratory conditions and multi-channel wet EEG electrodes may be a stressful experience for some athletes (e.g. young or autistic children) when having a large number of electrolytes put onto their heads [11]. Due to the development in technology, it has become easier to measure the mental status of individuals using mobile EEG devices [7, 14]. Some of the EEG devices adopted a single channel dry sensor and offer a wireless, ergonomic and pain-free EEG monitoring solution to researchers. Therefore, it is extremely easy-to-use for measuring the mental status of athletes during sport specific tasks [15, 16, 17]. Mobile devices can analyse brain waves using various algorithms and give the level of attention and meditation of people as a ratio [7]. Therefore, we hypothesized that the novices and experts would present different psychophysiological responses during the aiming period. The purpose of this study was to investigate the psychophysiological differences of expert and novice rifle shooters during the aiming period using a mobile EEG device.

Material and Methods

Participants. A total of 34 male rifle shooters including 14 experts (age: 28.08±9.12 years, height: 176.12±4.24 cm, weight: 73.56±5.28 kg) and 20 novices (age: 21.08±3.12 years, height: 177.42±3.74 cm, and weight: 71.56±3.57 kg) participated in this study. The experts were chosen from a group of national athletes having experiences of at least four years and the novice shooters were chosen from beginners (2-8 months). The participants did not have any health problems. The current study was approved by the local ethical council and applied in accordance with the Declaration of Helsinki. All the participants were informed of the objectives and risks of the study. All participants signed a voluntary participation form.

Research Design. To determine the psychophysiological differences between expert and novice rifle shooters during the aiming period the shooters performed five shootings from a distance of 10m. The averages of each shooter's five shooting scores, values of attention and meditation, and heart rate between 5-sec before shooting and shooting moment were obtained.

Procedure. The study was performed in a standard indoor shooting area. Firstly, descriptive statistical data of the participants were obtained. The shooters performed a total of 10 shots for familiarization. Furthermore, external viewers were placed in the competition area to create a competition environment. It was reported that athletes would be rewarded according to their performance.

Measurements.

Attention and meditation. A single-channel mobile and wearable electroencephalogram (EEG) device (MindWave®, NeuroSky, Inc., U.S.A.) was placed to the participants' head. Usability of detecting attention levels in an assessment exercise using NeuroSky portable EEG device has been demonstrated in many studies [18, 19, 20]. The EEG device was connected to the computer via Bluetooth to determine the attention and meditation levels of the participants. The attention level represents the intensity of the participant's mental focus. Meditation level shows the mental and calmness levels of the participants. The attention and meditation levels are scored between "0" and "100". "0" represents the lowest level, and "100" represents the highest level. "10.9" is the highest score, and "0" is the lowest score in rifle shooting. A mini software was developed in MATLAP program for the analysis of the raw data (attention and meditation) obtained from the Mobile EEG device. In this software, while a participant was shooting (shooting moment), a mark was placed between the data. Thus, the data of 5 seconds before the shot were analysed.

Heart rate. In order to determine the heart rate of the participants, the polar M400 (Polar Electro Oy, Kempele, Finland) was placed on the chest area of the participants. In order to synchronize the data, one of the researchers held the heart rate monitor behind the participant and when a participant shot, the investigator pressed the lap button of the monitor. The data obtained from the heart rate monitor were analysed by the Polar Protrainer5 software. The average heart rate of pre-5s of shooting was analysed.

Statistical Analysis.

SPSS 18.0 software was used for the statistical analysis of the data. Kolmogorov Smirnov test was used to determine whether the data were distributed normally. Mann-Whitney U was used in order to detect the difference between the groups. A value of $p<0.05$ was taken as the significance value. Cohen's d values were calculated to determine effect sizes. Cohen's d values were classified as small ($0.00 \leq d \leq 0.49$), medium ($0.50 \leq d \leq 0.79$), and large effects ($d \geq 0.8$) [21].

Results

It is seen in Table 1 that shooting scores (10,02 ±0,49 vs. 7,6±2,86, p<0,01, effect size 1.179) and meditation level (71,50±21,05 vs. 52,93±20,54, p<0,05, effect size

Table 1. Comparison of the psychophysiological responses of the expert and novice rifle shooters during the aiming period.

Variables	Expert $\bar{X}$ ±SD	Novice $\bar{X}$ ±SD	Effect size
Attention (level)	59.76±21.26	73.63±21.11*	0.655
Meditation (level)	71.50±21.05*	52.93±20.54	0.892
Heart rate (bpm)	98.67±7.12	105.34±12.12*	0.671
Shooting score (points)	10.02±0.49**	7.6±2.86	1.179

Notes: **: p<0.01, *: p<0.05

0.892) are significantly higher in the expert shooters, whereas attention level (73,63±21,11 vs. 59,76±21,26, p<0,05, effect size 0.655), and heart rate (105,34±12,12 vs. 98,67±7,12 bpm, p<0,05, effect size 0.671) are found higher in the novice shooters.

Discussion

The purpose of this study was to investigate the psychophysiological differences of expert and novice rifle shooters. At the end of the current study, it was seen that shooting scores and meditation level were significantly higher in expert shooters while attention level and heart rate were found higher in the novice shooters.

There are a limited number of studies in the literature examining psychophysiological factors in rifle shooters. In the present study, it was observed that the heart rate during the shooting was higher in the novice rifle shooters. Similar to the current study, Neumann & Thomas investigated heart rate differences of the elite and novice golf athletes during hitting the ball. They reported that the elite players had a lower heart rate when compared with novice players [16, 17]. Similarly et al reported that elite archers exhibited a lower heart rate when they were compared with novice archers during shooting [22]. Tremayne & Barry demonstrated that there was a slower reduction in heart rate levels prior to the shot in the experts pistol shooters when compared with the novice shooters [23]. It is well known that cognitive procedures increase or decrease heart rate during motor performance [24]. The reason of heart rate increment during shooting activity in novice shooter may be due to the turning of external attention (focusing on the effect of the movement) to internal attention (focusing on a person's body movement). It is well known that while external attention leads to a decrease in heart rate, inner attention leads to an increase in heart rate [25]. The best scores are managed during the external attention with a lower heart rate [26, 27]. Moreover, external attention facilitates the automatization of the movement [28]. With the focus on the inside, novice athletes might talk to themselves leading to an increased heart rate. Supporting this idea, in the current study, the meditation values of the novice shooters were found lower than the expert shooters [26]. This may mean that anxiety levels of the novice shooters are higher than the expert shooters. Moreover, it is well known that there is a relationship between elevation of anxiety and heart rate [29].

In the current study, the attention and meditation levels of the shooters were analysed with the mobile EEG measurement. It was determined that the novice shooters had higher attention levels than the expert shooters. In the literature, different results were found in the studies conducted to determine the attention differences according to the athletes' levels. Similar to the present study, Haufler et al. reported that elite shooters exhibited lower cortical activation during aiming in 15 elite and 21 novice shooters [30]. In another study, Deeny et al. reported that the elites exhibited lower alpha and beta values [8]. Hatfield et al. stated that the elite shooters had lower activation of the cerebral cortex compared to the novice shooters [31]. In contrast to the current study, Lee (2009) stated that the elite archers had a greater attention level at the release of the arrow than the novice archers [7]. Del Percio et al. also reported high levels of alpha and beta bands which were directly related to attention and meditation in elite pistol shooters [32]. Fronso et al. stated in a review study that elite and novice shooters used different strategies during aiming, and especially the elites increased their attention during the shooting [27]. The most important reason for finding different results is the use of different protocols in the measurements. In the present study, the average of the psychophysiological values between 5-sec before shooting and shooting moment were obtained and analysed. However, other investigators found higher attention levels in experts just before release or shot [7, 32). The most important reason for lower attention in the expert shooters before shooting may be the long period of sports specific practice. The shooters can focus on the movement economically after a long period of repetition and adapt to sport specific movements because effective motor performance is characterized by the biomechanical and metabolic act of performing the movement economically [33, 34, 35, 36]. Serrien and Brown demonstrated a decline in the alpha and beta band EEG activities when the athletes became more familiar with a motor task [37]. Experienced shooters exhibit more precise focusing strategies and more effective visual screening models [38]. Unlike experts, novices focus more on related or irrelevant points (not selectively). This means more cognitive processing. However, as practice increases, irrelevant stimuli are eliminated and environmental stimuli and clues related to the task are processed [39].

Other data obtained in the mobile EEG measurements were that the meditation levels of the expert shooters were higher than the novice shooters. Similarly, Lee determined that the meditation levels of the expert archers were higher than the novices. Doppelmayr et al. found that only experienced gun shooters had a steady increase in theta power in the last three seconds prior to shooting [40]. Lange et al. determined a lower coherence in the alpha band when began to draw with the nondominant hand compared to the dominant hand [41]. This may be explained by the fact that expert shooters have more external attention and novice shooters have more internal attention. The higher heart rate and lower meditation level before the shot indicated that the novice shooters were under high stress and anxiety during shooting. However, in the expert shooters, emotions seemed more controllable under stress. It is well known that equilibrium performance is the most important factor affecting shooting performance [3, 4, 5]. Era et al. found that a change of less than 10% of postural control affected shooting score of elite rifle shooters [42]. Moreover et al. determined a significant association between low tension and the results in the test shootings ($r = 0.42$, $P < 0.001$) [43]. As a result, it is estimated that the increase in the internal attention of the novice shooters and the decrease of the meditation level may affect the balance control, and, therefore, the shooting scores are affected negatively.

Conclusion

It was determined that the expert and novice rifle shooters presented different psychophysiological responses during the aiming period of shooting activities. According to these results, it was seen that while shooting scores and meditation level were significantly higher in the expert shooters, attention level, and heart rate were found higher in the novice shooters. It is suggested that the psychophysiological differences can be useful to categorize shooters and to provide feedback in training because it is important to develop programs according to group levels, especially in the development of mental training programs. In order to improve performance in novice shooters, focusing on psychological training (relaxation, and external attention) methods is recommended. In the future, studies can be carried out in rifle shooters together with the parameters of psychophysiological factors and balance control. Besides, it is determined that a mobile EEG device is an effective method for determining the mental status of athletes in sports specific activities. In the future, studies can be carried out in rifle shooters together with the parameters of psychophysiological and balance control.

Conflict of interests

The authors declare that there is no conflict of interests.

References

1. *ISSF Rules Changes for 2018-2020*. [Internet]. 2017 [cited 2017 Dec 18]. Available from: https://www.issf sports.org/news.ashx?newsid=2955
2. Selva Y, Salleh AF, Joseph S. Influence of body weight distribution in shooting performance of 10 m air rifle shooters. *2015 2nd International Conference on Biomedical Engineering (ICoBE),* Penang, Malaysia: IEEE; 2015, p. 1–4. https://doi.org/10.1109/ICoBE.2015.7235926.
3. Ihalainen S, Kuitunen S, Mononen K, Linnamo V. Determinants of elite-level air rifle shooting performance. *Scand J Med Sci Spor*, 2016; 26 (3): 266- 274. https://doi.org/10.1111/sms.12440
4. Şimşek D, Ertan H. Postural control and sport: postural sensor motor strategies and postural sway in different sport branches. *Spormetre Beden Egitimi ve Spor Bilimleri Dergisi,* 2011; 9 (3): 81-90 . https://doi.org/10.1501/Sporm_0000000203
5. Ball KA, Best RJ, Wrigley TV. Inter-and intra-individual analysis in elite sport: Pistol shooting. *Journal of Applied Biomechanics,* 2003; 19(1): 28- 38. https://doi.org/10.1123/jab.19.1.28
6. Yarrow K, Brown P, Krakauer JW. Inside the brain of an elite athlete: the neural processes that support high achievement in sports. *Nature Reviews Neuroscience*, 2009;10:585–96. https://doi.org/10.1038/nrn2672
7. Lee K. Evaluation of attention and relaxation levels of archers in shooting process using brain wave signal analysis algorithms. *Sci Sensitivity*, 2009; 12 (3): 341-350.
8. Deeny SP, Hillman CH, Janelle MC, Hatfield BD. Cortico-cortical communication and superior performance in skilled marksmen: An EEG coherence analysis. *J Sport Exercise Psy*, 2003; 25: 188- 204. https://doi.org/10.1123/jsep.25.2.188
9. Abel JL, Larkin KT. Anticipation of performance among musicians: Physiological arousal, confidence, and state-anxiety. *Psychol Music*, 1990; 18 (2):171- 182. https://doi.org/10.1177/0305735690182006
10. Berka C, Levendowski DJ, Cvetinovic MM, Petrovic MM, Davis G, Lumicao MN. Olmstead R. Real-time analysis of EEG indexes of alertness, cognition, and memory acquired with a wireless EEG headset. *International Journal of Human-Computer Interaction*, 2004; 17(2): 151- 170. https://doi.org/10.1207/s15327590ijhc1702_3
11. Wong SW, Chan RH, Mak JN. Spectral modulation of frontal EEG during motor skill acquisition: a mobile EEG study. *International Journal of Psychophysiology*, 2014; 91(1):16-21. https://doi.org/10.1016/j.ijpsycho.2013.09.004
12. Park JL, Fairweather MM, Donaldson DI. Making the case for mobile cognition: EEG and sports performance. *Neurosci Biobehav R*, 2015; 52:117- 130. https://doi.org/10.1016/j.neubiorev.2015.02.014
13. Vernon D, Egner T, Cooper N, Compton T, Neilands C, Sheri A, Gruzelier J. The effect of training distinct Neurofeedback protocols on aspect of cognitive performance. *Int J Psychol*, 2003; 47: 75- 85. https://doi.org/10.1016/S0167-8760(02)00091-0
14. Bertollo M, Tamburro G, Schinaia L, Chatel-Goldman J, Di Fronso S, Robazza C, Comani S. Hyperbrain features of team mental models within a juggling paradigm: a proof of concept. *Peer J*, 2016; 4: e2457 . https://doi.org/10.7717/peerj.2457
15. Lim CG, Lee TS, Guan C, Fung DSS, Zhao Y, Teng SSW. et al. A brain–computer interface based attention training program for treating attention deficit hyperactivity disorder. *PloS one,* 2012; 7(10); e46692 . https://doi.org/10.1371/journal.pone.0046692
16. Neumann DL. Thomas PR. The relationship between skill level and patterns in cardiac and respiratory activity during golf putting. *Int J Psychophysiol*, 2009; 72 (3): 276- 282. https://doi.org/10.1016/j.ijpsycho.2009.01.001
17. Neumann DL. Thomas PR. Cardiac and respiratory activity and golf putting performance under attentional focus instructions. *Psychol Sport Exerc*, 2011; 12 (4): 451- 459. https://doi.org/10.1016/j.psychsport.2011.02.002
18. Rebolledo-Mendez G. et al. Assessing neurosky's usability to detect attention levels in an assessment exercise. In: *International Conference on Human-Computer Interaction*. 2009 july 19-24. Berlin: Springer, Heidelberg, 2009. P. 149-158. https://doi.org/10.1007/978-3-642-02574-7_17
19. Ekandem JI, Davis TA, Alvarez I, James MT, Gilbert JE. Evaluating the ergonomics of BCI devices for research and experimentation. *Ergonomics*, 2012; 55(5): 592- 598. https://doi.org/10.1080/00140139.2012.662527
20. Johnstone SJ, Blackman R, Bruggemann JM. EEG from a single-channel dry-sensor recording device. *Clinical EEG and neuroscience*, 2012; 43(2): 112- 120. https://doi.org/10.1177/1550059411435857
21. Cohen J. *Statistical power analysis for the behavioral sciences*. NJ: Lawrence Erlbaum Associates; 1988.
22. Carillo AE. Autonomic nervous system modulation during an archery competition in novice and experienced adolescent archers. *J Sport Sci,* 2011; 29 (9): 913- 917. https://doi.org/10.1080/02640414.2011.568514

23. Tremayne P, Barry RJ. Elite pistol shooters: physiological patterning of best vs. worst shots. *Int J Psychophysiol*, 2001; 41 (1): 19- 29. https://doi.org/10.1016/S0167-8760(00)00175-6
24. Abernethy B, Maxwell JP, Masters RSW, Kamp JVD, Jackson RC. Attentional Processes in Skill Learning and Expert Performance. In: Tenenbaum G, Eklund RC, editors. *Handbook of Sport Psychology,* Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2012, p. 245–63. https://doi.org/10.1002/9781118270011.ch11
25. Radlo SJ, Steinberg GM, Singer RN, Barba DA, Melnikov A. The influence of an attentional focus strategy on alpha brain wave activity, heart rate and dart-throwing performance. *Int J Sport Psychol*. 2002; 33 (2): 205-217.
26. Vrbik A, Bene R, Vrbik I. Heart rate values and levels of attention and relaxation in expert archers during shooting. *Hrvatski športskomedicinski vjesnik*, 2015; 30(1): 21-29.
27. Fronso SD, Robazza C, Bortoli L, Bertollo M. Performance optimization in sport: a psychophysiological approach. *Motriz*, 2017; 23 (4): 1-7. https://doi.org/10.1590/s1980-6574201700040001
28. Wulf G, Shea C, Lewthwaite R. Motor skill learning and performance: a review of influential factors. *Medical education*, 2010; 44 (1): 75-84. https://doi.org/10.1111/j.1365-2923.2009.03421.x
29. Dishman RK, Nakamura Y, Garcia ME, Thompson RW, Dunn AL, Blair SN. Heart rate variability, trait anxiety, and perceived stress among physically fit men and women. *Int J Psychophysiol*, 2000; 37 (2): 121-133. https://doi.org/10.1016/S0167-8760(00)00085-4
30. Haufler AJ, Spalding TW, Santa Maria DL, Hatfield BD. Neuro-cognitive activity during a self-paced visuospatial task: comparative EEG profiles in marksmen and novice shooters. *Biol Psychol*, 2000; 53 (2-3): 131-160. https://doi.org/10.1016/S0301-0511(00)00047-8
31. Hatfield BD, Haufler AJ, Hung TM, Spalding TW. Electroencephalographic studies of skilled psychomotor performance. *J Clin Neurophysiol*, 2004; 21 (3): 144-156. https://doi.org/10.1097/00004691-200405000-00003
32. Del Percio C, Babiloni C, Bertollo M, Marzano N, Iacoboni M, Infarinato F, Comani S. Visuo-attentional and sensorimotor alpha rhythms are related to visuo-motor performance in athletes. *Hum Brain Mapp*, 2009; 30 (11): 3527-3540. https://doi.org/10.1002/hbm.20776
33. Daniels JT. A physiologist's view of running economy. *Med Sci Sport Exer*, 1985; 17: 332–338. https://doi.org/10.1249/00005768-198506000-00006
34. Lay B, Sparrow W, Hughes K, O'Dwyer N. Practice effects on coordination and control, metabolic energy expenditure, and muscle activation. *Hum Movement Sci*, 2002; 21: 807–830. https://doi.org/10.1016/S0167-9457(02)00166-5
35. Sparrow WA. The efficiency of skilled performance. *J Motor Behav*, 1983;15: 237–261. https://doi.org/10.1080/00222895.1983.10735299
36. Sparrow WA. *Energetics of human activity*. Champaign, IL: Human Kinetics; 2000.
37. Serrien DJ, Brown P. The integration of cortical and behavioral dynamics during initial learning of a motor task. *Eur. J. Neurosci*. 2003; 17: 1098–1104. https://doi.org/10.1046/j.1460-9568.2003.02534.x
38. Wrisberg CA. Levels of performance skill: From beginners to experts. *Handbook of sport psychology*, 2001; 2: 3-19.
39. Logan GD. Attention and preattention in theories of automaticity. *The American Journal of Psychology*, 1992; 105 (2): 317-339. https://doi.org/10.2307/1423031
40. Doppelmayr M, Finkenzeller T, Sauseng P. Frontal midline theta in the pre-shot phase of rifle shooting: differences between experts and novices. *Neuropsychologia*, 2008; 46 (5):1463-1467. https://doi.org/10.1016/j.neuropsychologia.2007.12.026
41. Lange RK, Godde B, Braun C. EEG correlates of coordinate processing during intermanual transfer. *Exp. Brain Res,* 2004; 159: 161–171. https://doi.org/10.1007/s00221-004-1942-x
42. Era P, Schroll M, Ytting H, Gause-Nilsson I, Heikkinen E, Steen B. Postural balance and its sensory – motor correlates in 75-year old men and women: A cross-national comparative study. *J Gerontol: Medical Sciences,* 1996; 51A: 53-63. https://doi.org/10.1093/gerona/51A.2.M53
43. Solberg EE, Berglund KA, Engen O, Ekeberg O, Loeb M. The effect of meditation on shooting performance. *Brit J Sport Med*, 1996; 30 (4): 342-346. https://doi.org/10.1136/bjsm.30.4.342

Information about the authors:

Yıldız M.; (Corresponding author)**;** http://orcid.org/0000-0003-3481-7775; mehmetyildiz@aku.edu.tr; The School of Physical Education and Sports Teaching, Afyon Kocatepe University; Afyonkarahisar 03200, Turkey.

Fidan U.; http://orcid.org/0000-0003-0356-017X; ufidan@aku.edu.tr; Faculty of Engineering, Biomedical Engineering, Afyon Kocatepe University; Afyonkarahisar 03200, Turkey.

Cite this article as:
Yıldız M., Fidan U. The psychophysiological differences between expert and novice rifle shooters during the aiming period. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):313-317.
https://doi.org/10.15561/18189172.2019.0606

Received: 19.06.2019
Accepted: 25.07.2019; Published: 30.09.2019

PSYCHOLOGY medical-biological problems of physical training and sports

Validity of testing and training using the kayak ergometer

Zanevskyy I.P.[1AC], Chodinow W.[2BDE], Zanevska L.H.[1DE]

[1]*Department of Informatics and Kinesiology, Lviv State University of Physical Culture, Lviv, Ukraine*
[2]*Department of Physical Culture, Technological and Humanistic University in Radom, Poland*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Purpose: The paper is dedicated to the problem of the strength testing and training using the ergometer rowing performance in the flat water kayak sport. The aim of the research was to create a model of validity based on the relationship between the ergometer and on-water performance competition rowing.

Material: Nineteen 15–17 years old male kayak rowers during the off-season were randomly divided into two groups. An experimental group trained according the same program as the control group, but two times a week a part of the common strength training exercises was substituted with a high-intensity strength training using the ergometer rowing. A whole amount of strength loading on all the rowers of the two groups was equal. Validity of testing and training of the ergometer rowing in the kayak sport was evaluated using interclass correlation between competition performance on 500 m on-water kayak and ergometer rowing.

Results: Strong significant correlation is revealed between competition performance of on-water kayak and ergometer rowing before and after the off-season ($|r|$ = 0.892, 0.902, p <0.001), that shows rather good validity. Other result of the correlation analysis shows good prognostic ability of the ergometer performance regarding competition performance of on-water kayaking ($|r|$ = 0.913).

Conclusions: The proposed model based on the relationship between the ergometer and on-water performance competition rowing shows rather good validity of the strength testing and training in the on-water kayak sport.

Keywords: flat-water kayaking, rowing, competition, performance, modelling.

Introduction

The kayak rowing is a strength-endurance type of sport and competition performance depends on factors such as aerobic and anaerobic power, physical power, rowing technique and tactics. Therefore, a rower has to develop several capacities in order to be successful and a valid testing battery of a rower has to include parameters that are highly related to rowing performance. Endurance training is the mainstay in rowing. For the 2000 m race, power training at high velocities should be preferred to resistance training at low velocities in order to train more specifically during the off-season. The specific training of the international rower has to be approximately 70% of the whole training time [1].

Rowing ergometers were designed with a purpose to simulate rowing indoor exercises. During the last several decades, rowing ergometers revolutionised the training and testing of kayak sportsmen [2]. The ergometers were primarily used to simulate biomechanical movements and physiological stresses associated with a specific force of kayak paddling. Several ergometers with different designs can be used by rowers as part of their indoor training [3].

The ergometers are used not only for training, but for testing of rowing techniques and mechanical efficiency of paddling, too. Michael et al. examined elite kayakers and identify a number of key biomechanical performance variables during maximal paddling on a custom kayak simulator. Results indicated a significantly greater mechanical efficiency during the right paddle stroke compared with the left ($p < 0.025$). In addition, analysing the effect of period, peak paddle force demonstrated a significant reduction when comparing the beginning to the middle and end of the simulated race respectively ($p < 0.025$). Examination of individual force profiles revealed considerable individuality, with significant variation in the time course of force application [4].

Greene, et al. studied the effect of ergometer design on rowing stroke mechanics. No differences were found in the mechanical energy delivered to the handle of the three ergometers; however, greater joint mechanical energy production of the lower limb reduced mechanical efficiency when rowing using the fixed ergometer. The fixed foot stretcher on the fixed ergometer acts to increase the inertial forces that the rower must overcome at the catch, increasing the moment and power output at the knee, and affecting the coordination pattern during the recovery phase [5].

Fleming et al. assessed muscle recruitment patterns and stroke kinematics during ergometer and on-water rowing to validate the accuracy of rowing ergometry. Their results suggest that significant differences exist while comparing recruitment and kinematic patterns between on-water and ergometer rowing ($p < 0.01$). These differences may be due to altered acceleration and deceleration of moving masses on-ergometer not perfectly simulating the on-water scenario [6].

Sarabon et al. formulated a paradigm that to improve validity of testing and training of a rowing ergometer means to reduce the discrepancy between the rowing ergometer and on-water rowing. With this purpose they evaluated the effect of rowing ergometer compliance

doi:10.15561/18189172.2019.0607

on biomechanical and physiological indicators during simulated 2,000-metre race of young competitive rowers. The study compared biomechanical characteristics and physiological responses during rowing on three devices: stable ergometer, transversally compliant ergometer, and frontally compliant ergometer with stroke rate, average force, power output, velocity and amplitude of the handle and stretcher or seat, heart rate and blood lactate were measured at 500 m intervals. Force and power at the stretcher were significantly lower ($p < 0.03$) for transversally compliant ergometer, while stroke rate and velocities of the handle and the seat were higher ($p < 0.01$). No significant differences were observed between stable and frontally compliant ergometer in biomechanical parameters. The lowest rowing performance was observed in frontally compliant ergometer ($p = 0.007$), and was accompanied with the highest average heart rate ($p = 0.031$). In the transversally compliant ergometer, rowers modified their technique, but were able to maintain physiological strain and performance. In contrast, frontally compliant ergometer had no effect on rowing biomechanics, but decreased rowing performance and increased physiological strain [7].

Benson et al. undertook comparison of rowing stationary and dynamic ergometer. Differences were more pronounced in males than females; this dichotomy may be more due to dynamic ergometer familiarity than sex. When rowing at a constant power output, all rowers used higher stroke rates and lower stroke forces on the dynamic ergometer as compared to the stationary ergometer. Cardiopulmonary demand was higher for all rowers, as measured by heart rate, and efficiency was lower [8].

Cycle training is an important training modality of elite rowers. Cycling is the preferred alternative to on-water and ergometer rowing as it provides a reduction in compressive forces on the thoracic cage and upper extremities while still creating a local and central acclimation to endurance training. Lindenthaler et al. used rowing and cycle ergometry to determine differences in physiological responses during rowing in elite male sportsmen. It is hypothesised, however, that there will be differences in physiological characteristics between ergometer rowing and cycling due to the principle regarding the specificity of training that elite rowers undertake. Understanding these differences will ensure more accurate training prescription when cycling [9].

Rowers regularly undertake rowing training within 24 h of performing bouts of strength training; however, the effect of this practice has not been investigated. Gee TI et al. evaluated the impact of a bout of high-intensity strength training on 2,000 m rowing ergometer performance and rowing-specific maximal power. This bout of high-intensity strength training resulted in symptoms of muscle damage and decrements in rowing-specific maximal power, but this did not affect 2,000 m rowing ergometer performance in highly trained rowers [10].

In order to validate ergometer usage in laboratory testing of athletes, a quantitative assessment of task specificity must be established. Literature validating task specificity of various ergometer designs, using cardio-respiratory or biomechanical variables such as kinematic and force data exist. The development of reliable, commercially available air-braked kayak ergometers has led to their usage in training and testing of elite flat-water kayakers. Investigations into the validity of on-ergometer versus on-water testing for metabolic and cardio-respiratory variables have concluded that while kayak ergometers accurately simulated physiological demands of short-term high-intensity kayaking, a biomechanical assessment was required to determine how accurately kayak ergometers simulated the on-water scenario. Significant differences exist while comparing recruitment and kinematic patterns between on-water and ergometer rowing. These differences may be due to altered acceleration and deceleration of moving masses on-ergometer not perfectly simulating the on-water scenario [11].

Lawton et al. reviewed strength testing and training of rowers and identified strength tests that were reliable and valid correlates (predictors) of ergometer rowing performance. They established strength, power, and muscular endurance exercises for weight room training, which are strong determinants of success in specific performance measures used to assess elite rowers ergometer rowing performance. The question is about the ergometer rowing performance validity. A reasonable answer was regarding further research to examine the on-water benefits associated with various strength training protocols, in the context of the training phase, weight division, experience and level of rower, if limitations to the reliability and precision of performance data can be controlled [12].

Validity of testing and training of the ergometer rowing in the kayak sport is studied basing on the relationships between anthropometric characteristics, metabolic and biomechanical parameters, strength variables and rowing ergometer and on-water performance time [13]. Although the competition performance on-water time should be a criterion of skills in the kayak sport, there has been little research interest in on-water time trials for assessing rowing performance [14].

Research hypothesis: validity of testing and training of the ergometer rowing could base on the prediction of interclass correlation between competition performance of on-water kayak and ergometer rowing.

Purpose: the aim of the research was to create a model of validity of the strength testing and training based on the relationship between the ergometer and on-water competition rowing.

Material and Methods

Participants

Nineteen 15–17 years old male kayak rowers were involved into the research (body mass: 74.7±3.1 kg, body length: 176.7±2.8 cm). All the participants were good healthy; they trained according to the program for sport schools on kayak rowing [15].

This study was approved in advance by Ethical Committee of Lviv State University of Physical Culture. Parents of each the young participant voluntarily provided written informed consent before participating. The procedures followed were in accordance with the ethical standards of the Ethical Committee on human experimentation.

Procedure

The research was done during the off-season from November to April. Participants were randomly divided into two groups. One of these groups (control) consisted nine rowers which trained according the curriculum [15]. A bout of strength training consisted pressing a rod lying on a back, pulling a rod lying on the breast, pulling and jerking of the weight, exercises on the bars, various multi-joint barbell exercises etc.

Another group (experimental) consisted ten rowers trained according the same program as the control group, but two times a week a part of the common strength training exercises was substituted with a high-intensity strength training using the ergometer rowing. A whole amount of strength loading of all the rowers of the two groups was equal.

A time of 500 m kayak competition on flat water rowing was measured just before the off-season beginning (to the end of October) and just after the off-season ending (at the early May). From the very beginning of the off-season and just before the off-season ending, a number of maximal intensity double strokes with the rowing ergometer were measured during one minute.

Statistical analysis

Variation of measurements was estimated with the coefficient of variation:

$$V = \frac{SD}{M}100\% \quad (1)$$

where *SD*: standard deviation, *M*: arithmetic mean. When V < 10%, variation is small, 10–20% − moderate, and V > 20% − great.

Relative changing of training and competitive results during the off-season was calculated with formula:

$$\delta_{A-B} = \frac{M_A - M_B}{M_B}100\% \quad (2)$$

where M_A, M_B are arithmetic means of groups' results after and before the off-season.

Relative difference of competitive results between the experimental and control groups was calculated with formula:

$$\delta_{E-C} = \frac{|M_E - M_C|}{M_E + M_C}200\% \quad (3)$$

where M_E, M_c are arithmetic means of groups' results after and before of the off-season.

Validity of testing and training of the ergometer rowing in the kayak sport was studied in the frames of concurrent validity that refers to a measurement device's or method's ability to vary directly with a measure of the same construct. It allows showing that test is valid by comparing it with an already valid test [16].

The competition performance time was recognised as valid because in kayaking sport like any other sport the competition performance is an imperative matter. Validity of testing and training of the ergometer rowing in the kayak sport was evaluated using interclass correlation between competition performance of on-water kayak and ergometer rowing.

Shapiro – Wilk test was used to evaluate probability of a normal distribution of results showed by the research groups. The results were elaborated using parametric statistics of centre and variation.

Fisher − Snedecor F-test was used to determine significance of differences in variations between the experimental and control groups. Student t-test for paired samples was used to determine significance of changing in rowing results during the off-season. Student t-test for independent samples was used to determine significance of differences between mean values of the experimental and control groups.

Validity of testing and training on the ergometer rowing in the kayak sport was evaluated using Pearson paired correlation between on-water kayak and ergometer performance rowing. Significance of the correlation was estimated with Student t-test for interclass correlation using the formula as follows:

$$t = |r|\sqrt{\frac{n-2}{1-r^2}} \quad (4)$$

where *r* is coefficient of correlation, *n* − number of participants in a group.

The computer package Statistica was used in data processing.

Results

Because near normal distribution (*SW-W* = 0.899−0.951, *p* = 0.215−0.695), parametric statistics were used to elaborate results of competitions and training (Table 1). During the off-season, both groups increased competition results in rowing ($p < 0.001$), but the experimental group showed significantly greater decrease of rowing time (3.3 s, 2.6%) than the control group: (1.9 s, 1.6%). Much more great increase was noticed in a number of double strokes with the rowing ergometer (11.2, 36.6%). Significance of the noticed increase in all the results is confirmed with paired correlation of the beginning and ending results ($r = 0.939−0.996$, $t < 0.001$).

Before the beginning of the off-season, experimental and control groups showed practically equal results in the water rowing competition: $p = 0.922$ (Table 2), but after the end of the off-season the experimental group convincingly surpassed the control group ($p = 0.160$). Groups variations of results in water rowing competition and ergometer rowing were rather small ($V < 10\%$), but variations of water rowing competition were times smaller ($V < 2\%$), than ergometer rowing ($V = 6.7$, 7.9%).

Rather strong significant correlation was revealed between competition performance of on-water kayak and ergometer rowing before ($r = −0.892$, $p < 0.001$) and after the off-season: $r = −0.902$ (Table 3). Other result of the correlation analysis showed really good prognostic ability of the ergometer performance regarding competition

Table 1. Bias of results during the off-season

Group	EG (kayak)		CG (kayak)		EG (ergometer)	
Competition	Before	After	Before	After	Before	After
n	10		9		10	
M (s)	122.2	118.9	122.3	120.4	30.6	41.8
SD (s)	2.4	2.1	2.2	2.0	2.4	2.8
Max (s)	125.0	121.5	125.1	123.0	35.0	46.0
Min (s)	117.9	115.0	119.0	117.3	28.0	38.0
V (%)	2.0	1.8	1.8	1.7	7.9	6.7
SW-W	0.899	0.933	0.942	0.951	0.903	0.928
p	0.215	0.482	0.606	0.695	0.236	0.426
$D_{A\text{-}B}$ (s/times)	–3.3		–1.9		11.2	
$d_{A\text{-}B}$ (%)	–2.6		–1.6		36.6	
t*	11.9		21.9		44.9	
$t_{0.001,\, n\text{-}1}$	4.8		5.0		4.8	
*r**	0.939		0.996		0.964	

Note: *n* – number of rowers; *M* – arithmetic mean; *SD* – standard deviation; *Max* – maximal; *Min* – minimal; *V* – coefficient of variance; *SW-W* – Shapiro–Wilk parameter; *p* – significance; Δ – difference between ending and beginning results at the off-season; *t* – Student statistics; *r* – correlation coefficient; * $p < 0.001$.

Table 2. Comparison of groups' on-water competition performance time regarding off-season

Competition	Before		After	
Group	Experimental	Control	Experimental	Control
n	10	9	10	9
M (s)	122.2	122.3	118.9	120.4
MS (s^2)	6.0	4.9	4.6	4.1
Δ (s)	–0.1		–1.5	
$d_{E\text{-}C}$ (%)	–0.1		–1.2	
F	1.228		1.119	
p(F)	0.391		0.443	
t	0.099		1.470	
p(t)	0.922		0.160	

Note: *n* – number of rowers; *M* – arithmetic mean; *MS* – variance; $\Delta_{E\text{-}C}$ – difference between groups; *F* – Fisher–Snedecor statistics; *t* – Student statistics; *p(t)*, *p(F)* – significance regarding mean values and variances correspondingly.

performance of on-water kayaking ($r = -0.913$).

These correlations have negative direction ($r < 0$), because in average decreasing of the on-water competition performance time was accompanied with increasing of a number of double strokes in the ergometer performance (Figure 1). Of course, correlations between one-named results before and after off-season have positive direction ($r > 0$), namely for the on-water competition performance time it was 0.939 ($p < 0.001$) and for the number of double strokes in the ergometer performance – 0.964. These two coefficients confirm results of statistical hypothesis regarding changing of results of the on-water competition performance time and of the number of double strokes in the ergometer performance during the off-season. The same hypothesis regarding the control group showed a similar result: $r = -0.996$, $p < 0.001$ (see Table 1).

Discussion

The aim of the research was to create a model of validity of testing and training based on the relationship between the ergometer and on-water performance competition rowing. The model of validity derived in the research could be useful to validate investigations on relationships between results of tests and exercises and ergometer rowing performance.

Rowing races require developing high level of force and power output at high contraction velocity. Giroux et al. determined the force-velocity and power-velocity profiles of lower and upper limbs of adolescent rowers and their relationships with a 1,500-m rowing ergometer performance. The power developed during the 1,500-m (P_{1500}) was evaluated in fourteen national-level male rowers 15.3±0.6 years old. The profiles were assessed during bench pull and squat jump exercises [17].

Maciejewski et al. investigate whether three different approaches for evaluating squat jump performance were correlated to rowing ergometer performance in elite adolescent rowers, who performed a 1,500-m all-out rowing ergometer performance and a squat jump test. The performance in the test was determined by calculating the jump height, a jump index, and the mean power output [18, 19]. According to the model created one could use analysis of correlation between ergometer and on-water rowing competition performances with a purpose to evaluate validity of these tests.

The same recommendation regarding validity of the ergometer rowing performance could be directed to examination of the anthropometric and metabolic determinants of performance during 6,000-m of rowing on an ergometer and prediction of the 1000m rowing ergometer performance in young rowers [20].

The ergometer rowing during one minute was directed to strength training that is in harmony with recommendations by Lawton et al. While strength partially explained variances in 2000-m ergometer performance, concurrent endurance training may be counterproductive to strength development over the shorter term. Therefore, prioritization of strength training within the sequence of training units should be considered, particularly over the non-competition phase. Maximal strength was sustained when infrequent (e.g. one or two sessions a week) but intense (e.g. 73-79% of maximum) strength training units were scheduled; however, it was unclear whether training adaptations should emphasize maximal strength, endurance or power in order to enhance performance during the competition phase [21, 22].

The use of the ergometer rowing showed some training effect. With the same whole amount of the strength loading as in the control group, the experimental group using the ergometer rowers during off-season showed better on-water competition performance on the 500 m distance: 1.5 s, $p = 0.160$ (see Table 2).

Garcia-Pallares and Izquierdo investigated strategies to optimize concurrent training of strength and aerobic fitness for rowing and canoeing and recommend

Table 3. Correlation between of on-water kayaking and ergometer rowing performance regarding off-season

Measurements		**Ergometer**		**Kayak**	
		Before	**After**	**Before**	**After**
Ergometer	Before	–	10.21◊	5.59◊	6.35◊
	After	0.964*	–	6.14◊	5.91◊
Kayak	Before	–0.892*	–0.908*	–	7.70◊
	After	–0.913*	–0.902*	0.939*	–

Note: *r – coefficient of correlation; ◊t – Student statistics; p <0.001.

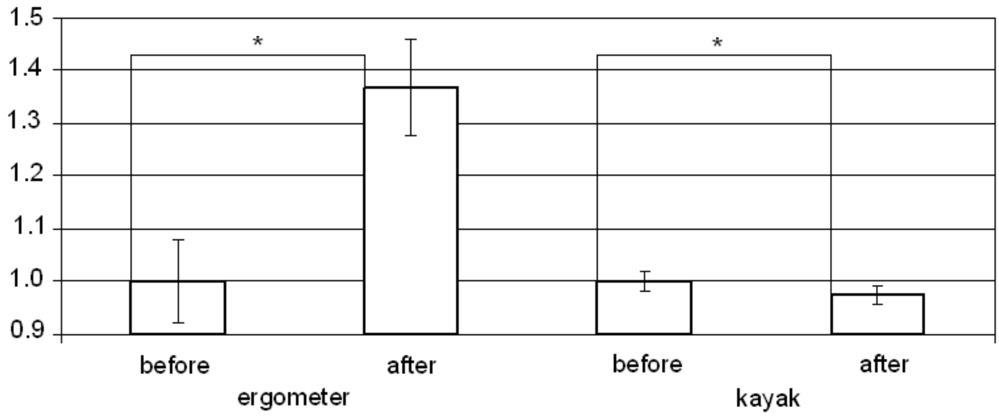


Figure 1. Relative results of the experiment group about the off-season ($M \pm SD$), *$p < 0.001$.

strategies, based on research, to avoid or minimize any interference effect when training to optimize performance in these endurance sports [23]. The created model of validity based on the strength preparation of kayak rowers performed competition on the short distances (200, 500 m). Analogical models could be created for the endurance preparation regarding long competition distances.

The model of the ergometer performance validity was derived on the male rowers results. There are no clear restrictions to disseminate this model on the female sport kayaking, but it should be a problem of a special research [24].

Conclusions

A problem of the ergometer performance rowing validity should be considered taking into attention the ultimate aim of rowing sports – on-water competition performance time. The coefficient of correlation between the ergometer and on-water competition performance time is a quantitative measure of this validity. The model could used as rather good prognostic instrument that was showed on the example of young kayak rowers during the off-season ($|r| = 0.913$, $p < 0.001$). The ergometer rowing has some training effect on the 500 m distance ($p = 0.160$).

Information on financial support

The authors declare no financial support regarding this paper.

Conflict of Interest

The authors declare that there is no conflict of interest regarding this research.

References

1. Maestu J, Jurimae J, Jurimae T. Monitoring of performance and training in rowing. *Sport Med.,* 2005; 35(7): 597-617. https://doi.org/10.2165/00007256-200535070-00005
2. Fleming N, Donne B, Fletcher D, Mahony N. A biomechanical assessment of ergometer task specificity in elite flatwater kayakers. *J Sports Sci Med*, 2012;11:16–25.
3. Johann V, Nordez A, Smith R, Colloud F. Asymmetry in elite rowers: effect of ergometer design and stroke rate. *Sport Biomech*. 2015; 14 (3): 310-322. https://doi.org/10.1080/14763141.2015.1060252
4. Michael JS, Smith RM, Rooney KB. The dynamics of elite paddling on a kayak simulator. *J Sport Sci*. 2012; 30(7): 661-668. https://doi.org/10.1080/02640414.2012.655303
5. Greene AJ, Sinclair PJ, Dickson MH, Colloud F, Smith RM. The effect of ergometer design on rowing stroke mechanics. *Scand J Med Sci Sports*. 2013; 23 (4): 468-477. https://doi.org/10.1111/j.1600-0838.2011.01404.x
6. Fleming N, Donne B, Mahony N. A comparison of electromyography and stroke kinematics during ergometer and on-water rowing. *J Sport Sci*. 2014; 32 (12): 1127-1138. https://doi.org/10.1080/02640414.2014.886128
7. Šarabon N, Kozinc Ž, Babič J, Marković G. Effect of Rowing Ergometer Compliance on Biomechanical and Physiological Indicators during Simulated 2,000-metre Race. *J Sports Sci Med*, 2019;18:264–70.
8. Benson A, Abendroth J, King D, Swensen T. Comparison of rowing on a concept 2 stationary and dynamic ergometer. *J Sports Sci Med*. 2011; 10 (2): 267-273.
9. Lindenthaler JR, Rice AJ, Versey NG, McKune AJ, Welvaert M. Differences in physiological responses during rowing and cycle ergometry in elite male rowers. *Front Physiol*. 2018; 9: 1010. https://doi.org/10.3389/fphys.2018.01010
10. Gee TI, French DN, Howatson G, Payton SJ, Berger NJ, Thompson KG. Does a bout of strength training affect 2,000 m rowing ergometer performance and rowing-specific maximal power 24 h later? *Eur J Appl Physiol*. 2011; 111 (11): 2653-2662. https://doi.org/10.1007/s00421-011-1878-3
11. Fleming N, Donne B, Mahony N. Electromyographic and kinesiological analysis of the kayak stroke: comparison of on-water and on ergometer data across exercise intensity. In: Hoppeler H, Reilly T, Tsolakidis E, Gfeller L, Klossner S (eds), *Proceeding of the 12th annual congress of the European college of sports sciences; 2007 Jul 11-14*; Jyvaskyla, Finland; 2007. P. 1744.
12. Lawton TW, Cronin JB, McGuigan MR. Strength testing and training of rowers: a review. *Sport Med*. 2011; 41 (5): 413-432. https://doi.org/10.2165/11588540-000000000-00000
13. Russell AP, Le Rossignol PF, Sparrow WA. Prediction of elite schoolboy 2000m rowing ergometer performance from metabolic, anthropometric and strength variables. *J Sports Sci*. 1998; 16 (8): 749-754. https://doi.org/10.1080/026404198366380
14. Smith TB, Hopkins WG. Measures of rowing performance. *Sports Med*. 2012; 42 (4): 343-358. https://doi.org/10.2165/11597230-000000000-00000
15. Vorontsov YO, Maslachkov YM, Cherednichenko OO, Sheptytskiy VV, Simanovskiy AB, Vikhlayeva TM et al. *Curriculum for sport schools on kayak, canoe, and slalom rowing* [document on the Internet]. Kyiv: Ukrainian Rowing Federation; 2007. [cited 2019 Jul 31]. Available from: https://dniprorada.gov.ua/upload/editor/baidarki_kanoe_1_2.pdf. (in Ukrainian)
16. *Cronbach LJ, Meehl PE. Construct validity in psychological tests. Psychol Bull. 1955; 52 (4): 281–302.* https://doi.org/*10.1037/h0040957*
17. Giroux C, Maciejewski H, Ben-Abdessamie A, Chorin F, Lardy J, Ratel S et al. Relationship between force-velocity profiles and 1,500-m ergometer performance in young rowers. *Int J Sports Med*. 2017; 38 (13): 992-1000. https://doi.org/10.1055/s-0043-117608
18. Maciejewski H, Rahmani A, Chorin F, Lardy J, Samozino P, Ratel S. Methodological Considerations on the Relationship Between the 1,500-M Rowing Ergometer Performance and Vertical Jump in National-Level Adolescent Rowers: Journal of Strength and Conditioning Research 2018:1. https://doi.org/10.1519/JSC.0000000000002406
19. Mikulic P. Anthropometric and metabolic determinants of 6,000-m rowing ergometer performance in internationally competitive rowers. *J Strength Cond Res*. 2009; 23 (6): 1851-1857. https://doi.org/10.1519/JSC.0b013e3181b3dc7e
20. Mikulic P, Ruzic L. Predicting the 1000m rowing ergometer performance in 12-13-year-old rowers: the basis for selection process? *J Sci Med Sport*. 2008; 11 (2): 218-226. https://doi.org/10.1016/j.jsams.2007.01.008
21. Lawton TW, Cronin JB, McGuigan MR. Strength, power, and muscular endurance exercise and elite rowing ergometer performance. *J Strength Cond Res*. 2013; 27 (7): 1928-1935. https://doi.org/10.1519/JSC.0b013e3182772f27

22. Lawton TW, Cronin JB, McGuigan MR. Does on-water resisted rowing increase or maintain lower-body strength? *J Strength Cond Res*. 2013; 27 (7): 1958-1963. https://doi.org/10.1519/JSC.0b013e3182736acb
23. García-Pallarés J, Izquierdo M. Strategies to optimize concurrent training of strength and aerobic fitness for rowing and canoeing. *Sports Med*. 2011; 41 (4): 329-343. https://doi.org/10.2165/11539690-000000000-00000
24. Chodinow W. Wpływ danych antropometrycznych i przygotowania fizycznego na wyniki specjalistycznych testów kajakarek [The influence of anthropometric results of physical preparation for specialized kayak results]. *Moloda sportivna nauka Ukraini,* 2010; 14(1): 353-358. (in Polish)

Information about the authors:

Zanevskyy I.P.; (Corresponding author)**;** http://orcid.org/0000-0002-9326-1167; izanevsky@ukr.net; Department of Informatics and Kinesiology, Lviv State University of Physical Culture; Kostyushka 11, 79007 Lviv, Ukraine.

Chodinow W.; http://orcid.org/0000-0003-4414-5407; brig@interia.pl; Department of Physical Culture, Technological and Humanistic University in Radom; Chrobrego 27, Radom 26-600, Poland.

Zanevska L.H.; http://orcid.org/0000-0001-9279-2372; lzanevska@ukr.net; Department of Informatics and Kinesiology, Lviv State University of Physical Culture; Kostyushka 11, 79007 Lviv, Ukraine.

Cite this article as:
Zanevskyy IP, Chodinow W, Zanevska LH. Validity of testing and training using the kayak ergometer. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):318-324.
https://doi.org/10.15561/18189172.2019.0607

Received: 02.08.2019
Accepted: 15.09.2019; Published: 30.09.2019

Impact of coordination training on the development of speed among young judokas from 10 to 12 years old

Zeghari L.[ABCD], Moufti H.[ABCD], Arfaoui A.[CD], Gaidi.A.[AB], Addal K.[AB]

Royal Institute of Management training, National Center of Sports Moulay Rachid, Salé, Morocco

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: Judo is a combat sport requiring physical qualities that include speed and coordination. They are essential for brief and intense attacks. Study the impact of a training based on coordination adapted to the age group (10 to 12 years) on the development of speediness among young's judokas.

Material: The study was conducted at Svelty Club, sports association in Kenitra, city in north-western Morocco, from March 2nd, 2019 to May 5th, 2019, on a sample of 12 young judoka aged from 10 to 12 years divided into two groups, control group and experimental group. At first both groups received two tests, 10m speed test and Uchi Komi test, which we considered initial tests. The experimental group had a training program spread over 12 weeks that focused on the development of speed through coordination. For the control group, we followed the regular training of the club. Both tests were re-administered after the end of the training program (final tests).

Results: The initial test value for the experimental group for Uchi Komi test was 7 ± 0.9, and the final test was 8.7 ± 1.03, which shows a significant difference according to the T test, ($p = 0.001 \leq 0.05$) in contrast to the control group ($p = 0.23 \geq 0.05$). For the 10m speed test, the experimental group showed a significant difference between the value of the initial test and the final test ($p = 0.003 \leq 0.05$), unlike the control group ($p = 0.93 \geq 0.05$).

Conclusions: The development of physical qualities is still the primary goal of coaches; however this development is more decisive for young athletes. Our study has shown that a coordination training adapted to each athlete's age can help coaches better develop other qualities namely speed.

Keywords: training, young, speed, coordination, judo, athlete.

Introduction

Judo is a highly demanding fighting sport. It requires the development of speediness for brief and intense maneuvers alongside endurance through the repetition of attacks. Furthermore, it prizes the mastery of coordination for an efficient execution of movements. A judo battle is composed of a succession of intermittent, brief and intense efforts, lasting a total of seven to eight minutes and inducing a strong demand of the different energy sectors [1-3].

A perfect physical condition is necessary for an optimal expression of the techniques that define the success of a judoka [4, 5]. For judo practitioners under 12 years of age the situation is a little more intricate. If the charge is univocal, early hyper-specific training can be problematic promoting muscle imbalances that could subsequently alter these young Judokas' development. Many children would not develop their maximum sport potential simply because the stimuli applied during their growth were insufficient or unambiguous. [6-8].

Hypothesis: Specific coordination training will have an impact on the development of speed among an age group of judokas from 10 to 12 years old.

Purpose: Study the impact of a training based on coordination adapted to the age group (10 to 12 years) focusing on the development of speediness among these young judokas through two tests, a speed test on 10m and a specific test Uchi Komi; a fundamental exercise in the physical and technical preparation of judoka [9].

doi:10.15561/18189172.2019.0608

Material and methods

Participants:

The present study was conducted at Svelty Club, sports association founded on October 13, 2013 in Kenitra, city in north-western Morocco, which contains over 80 licensees. The study was conducted from March 3rd, 2019 to May 4th, 2019, all Tuesday, Thursday and Saturday from 7 PM to 8 PM.

The population is made up of 12 male judokas from the club ASSOCIATION SVELTY CLUB. These subjects were chosen in a random way, forming two groups:

- *An experimental group* whose age was between 10 and 12 years, with a mean age of 11.33 ± 1.03, and a weight between 41 and 78 kg and a mean of 53.33 ± 14.65.
- *A control group* whose age was between 10 and 12 years, with a mean age of 11.33 ± 1.03, and a weight between 40 and 55 kg, and a mean of 46.16 ± 5.78.

Research Design:

Before applying the tests, both experimental and control groups perform specific warm-up exercises to avoid injury and prepare the muscle for exertion by increasing body temperature.

Step 1: Applying the initial tests to assess the initial level of each member of both groups (experimental and control).

Test 1: Speed test on 10m:

- The subject must be behind the starting line, the stopwatch is triggered when the subject's rear foot leaves the ground, and stops when he crosses the finish line, the subject must perform 3 tries and the best time is recorded

[10], the objective of this test is to evaluate the ability to start explosively.

Test 2: Uchi komi:

- The subject must perform the maximum number of repetitions on ippon-seoi-nage for 10 seconds, he must keep the rhythm adopted from the outset and especially the gestural quality at the time of execution of the technical gesture [11], however the test procedure must comply with the following conditions:
- Rotate completely and return from the front,
- Both feet on the same line,
- The hand back on the reverse.

Step 2: Development of an adapted training program focused on speed development through coordination (see Appendix):

After initial testing, we set up a specific training plan to develop speed among young judokas aged 10 to 12 years, while taking into consideration the fundamental principles of progression (from simple to complex), respect the stages of development, the load of the exercises and the principle effort-recovery.

The training program was spread over a period of 12 weeks, with three training sessions per week, making a total of 36 sessions lasting 60 minutes each.

Step 3: repeat the tests (10m speed test and Uchi Komi test) under the same conditions of the initial tests that we will consider final tests.

Statistical analysis:

For the analysis of the evolution between the two groups we chose T test of the paired samples, with the software SPSS version 25.

Results

Descriptive results

According to Table 1 the experimental group has a mean age of 11.33 ± 1.03, and the average of the results of the initial and the final test for the speed in 10 meters are respectively (2.35 ± 0.09), (2.25 ± 0.06).

For Uchi Komi test the mean of the initial and final test results are respectively (7 ± 0.9), (8.7 ± 1.03).

From Table 2 the control group has a mean age of 11.33 ± 1.03, as well as the average of the results of the initial and the final test for the speed in 10 meter are respectively (2.61 ± 0.25), (2.60 ± 0.19).

For Uchi Komi test the average of the initial and final test results are respectively (6.67 ± 1.37), (7.67 ± 1.21).

Results of the comparison between the experimental group and the control group.

- Speed test on 10m in (s)

- For the experimental group and from Table 3, the average of the initial test was 2.35 ± 0.09, and the final test was 2.25 ± 0.06, which proves an evolution of 0.1 (s). And this is confirmed by the paired sample T-test, which shows that there is a significant difference between the value of

Table 1. General characteristics of the sample as well as the results of the initial and final tests of the two tests (speed over 10 m and Uchi Komi by 10 seconds (Ippon Seoi Nage)) for the experimental group.

Subjetcs	Ages (years)	Weight (kg)	Grades	IT*: 10m (s)	FT*: 10m (s)	IT : Uchi Komi	FT: Uchi Komi
1	12	43	Blue	2.30	2.18	8	10
2	12	59	Blue	2.41	2.32	8	9
3	10	41	Blue	2.47	2.33	6	7
4	12	78	yellow	2.25	2.19	7	9
5	12	58	white	2.29	2.25	7	9
6	10	41	white	2.40	2.25	6	8
****	11.33±1.0	53.3±14.65	****	2.35±0.09	2.25±0.06	7±0.9	8.7±1.03

Note: IT*: Initial test, FT*: Final test.

Table 2. General characteristics of the sample as well as the results of the initial and final tests of the two tests (speed over 10 m and Uchi Komi by 10 seconds (Ippon Seoi Nage)) for the control group.

Subjects	Ages	weight (kg)	Grades	IT*: 10m (s)	FT 10m (s)	IT*: Uchi Komi	FT*: Uchi Komi
1	12	40	Blue	2,15	2,29	9	7
2	10	40	Green	2,70	2,71	7	9
3	12	55	Orange	2,85	2,65	7	9
4	12	45	Orange	2,60	2,50	6	6
5	12	48	White	2,81	2,86	5	8
6	10	49	white	2,53	2,60	6	7
****	11.33±1.03	46.16±5.7	*****	2.61±0.25	2.60±0.19	6.67±1.37	7.67±1.21

Note: IT*: Initial test, FT*: Final test.

Table 3. Comparison of the initial and the final test of 10m speed test between the two groups

Experimental Groupe			Control Groupe		
Initial test	**Final test**	**Sig***	**Initial test**	**Final test**	**Sig***
A*± Sd*	A*± Sd*	0.003	A*± Sd*	A*± Sd*	0.93
2.35±0.09	2.25±0.06		2.61±0.25	2.60±0.19	

Note: A*: average, Sd*: standard deviation Sig*: signification.

Table 4. Comparison of the initial and the final test of Uchi Komi test of 10 seconds (Ippon Seoi Nage) between the two groups

Experimental Groupe			Control Groupe		
Initial test	**Final test**	**Sig***	**Initial test**	**Final test**	**Sig***
A*± Sd*	**A*± Sd***	0.001	**A*± Sd***	**A*± Sd***	0.23
7±0.9	8.7±1.03		6.67±1.37	7.67±1.21	

Note: A*: average, Sd*: standard deviation Sig*: signification.

the initial test and the final test ($p = 0.003 \leq 0.05$).

- For the control group and from Table 3, the average of the initial test was 2.61 ± 0.25, and the final test was 2.60 ± 0.19, which proves a difference of 0.01, but based on the paired T-samples test, we can see that there is no statistically significant difference ($p = 0.93 \geq 0.05$).

- Uchi Komi test of 10 seconds (Ippon Seoi Nage)

- For the experimental group and from Table 4, the average of the initial test was 7 ± 0.9, and the final test was 8.7 ± 1.03, which proves an evolution of about 1.7 And this is confirmed by the paired sample T test, which demonstrates that there is a significant difference between the value of the initial test and the final test ($p = 0.001 \leq 0.05$).

- For the control group and from Table 4, the average of the initial test was 6.67 ± 1.37, and the final test was 7.67 ± 1.21, which proves a difference of the order of 1, but based on the T-test of paired samples, we find that this evolution is not statistically significant ($p = 0.23 \geq 0.05$), and thereafter it is not considerable.

Discussion

According to Table 1 and 2, the experimental group and the control group have the same middle age (11.33 ± 1.03), and this was part of the sample choices in order to have the same starting conditions for both study groups.

According to both Tables 3 and 4, comparing the results of the initial test (2.35 ± 0.09) and final test (2.25 ± 0.06) for the test of speed of 10 meters for the experimental group, we manage to have an evolution of the order of 0.1 (s), and this is was confirmed by the T-test of paired samples, which shows that there is a significant difference between the value of the two initial and final tests ($p = 0.003 \leq 0.05$). The same result was recorded for Uchi Komi test ($p = 0.001 \leq 0.05$), between the initial test (7 ± 0.9) and the final test (8.7 ± 1.03), while in the control group the results for either the 10m speed test or Uchi Komi test are not significant respectively ($p = 0.93 \geq 0.05$), ($p = 0.23 \geq 0.05$).

These encouraging results can only be explained by the effectiveness of the training program developed and applied during the experimental period (12 weeks), and of course by the impact of coordination on the development of physical qualities, and this was widely discussed in several scientific articles on judo and other combat sports: fencing [12-15], judo [16-18], wrestling [19, 20], kickboxing [21, 22], taekwondo [19, 21, 23], but other authors put forward very different and different opinions regarding the experimental data on the importance of particular coordination in combat sports, a researcher named Petrow in 1997 [24], claims that no scientist has further determined the structure of coordination motor skills that significantly affect performance in certain combat sports.

Conclusion

The development of physical qualities is still the primary goal of coaches; however, this development is more decisive for young athletes. Our study has shown that a coordination training that is age adapted can help coaches better develop a number of qualities namely speediness.

Thanks

To the entire staff of Svelty club, and especially to the coach Mr Safouane Attaf for the help he has given us to develop this work, and for his valuable contribution and advice throughout the realization of this job.

Contributions of the authors

All the authors contributed to the conduct of this work.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Ebine K. Physiological characteristics of exercise and findings of laboratory tests in Japanese elite judo athletes. *Médicine du Sport*. 1991; 65: 73-79.
2. Favre-Juvin A, Majean H, Gaillat L, Eterradossi J. Approche physiologique du judo [Physiological approach of judo]. *Med Sport*; 1989; 40: 5–10. (In French)
3. Monteiro LF. Structure et coût énergétique des combats de judo [Structure and energy cost of judo fights]. *2nd International Judo Federation World Judo Conference in Munich, Germany*. 2001. P. 100-107. (In French)
4. Houvenaeghel M. Mesure continue de la fréquence cardiaque en entraînement spécifique de judo [Continuous measurement of heart rate in specific judo training]. *Science & sports*. 2005; 20(1) :27-32. (In French) https://doi.org/10.1016/j.scispo.2004.05.009
5. Jagiello W. Differentiation of the body composition in taekwondo-ITF competitors of the men's Polish national team and direct based athletes. *Archives of Budo*. 2015;11:329-38.
6. Vandeberg D, Weemaels G. Ds Athletic Academy: une approche progressive pour favoriser le développement optimal des qualités [Physiques a progressive approach to foster the optimal development of physical qualities]. *Science & Sports*. 2014; 29: S32. (In French) https://doi.org/10.1016/j.scispo.2014.08.066
7. Doroshenko EY, Svatyev AV, Iermakov SS, Jagiello W. The use of cardio training facilities in training 7-9-year-old judo athletes. *Archives of Budo Science of Martial Arts and Extreme Sports*. 2017;13:165-72.
8. Osipov AY, Kudryavtsev MD, Iermakov SS, Jagiello W, Doroshenko SA. Development of the ability to maintain body balance in young athletes 12-13 years practicing judo. *Archives of Budo Science of Martial Arts and Extreme Sports,* 2018;14:21–30.
9. Almansba R, Franchini E, Sterkowicz S. Uchi-komi avec charge, une approche physiologique d'un nouveau test spécifique au judo [Uchi-komi with load, a physiological approach of a new specific test to judo]. *Science & Sports*. 2007; 22(5): 216-223. (In French) https://doi.org/10.1016/j.scispo.2007.06.006
10. Lefevre T. *Etude des effets de la fréquence cardiaque d'entrainement en vitesse* [Study of the effects of speed training heart rate]. 2014. (In French)
11. Paillard T. *Optimisation de la performance sportive en judo Optimization of sport performance in judo*. De Boeck Supérieur; 2010. (In French)
12. Sadowski Jerzy. Dominant coordination motor abilities in combat sports. *Journal of human kinetics*. 2005; 13: 61.
13. Kriventsova I, Pashkevych S, Iermakov S, Bartik P, Michal J, Nosko M, et al. Fitness - aerobic training of 15 - 17 years' age girl students, who have significant risk of deviations in backbone functional state. *Journal of Human Sport and Exercise*. 2017;12(4):1289-1297. https://doi.org/10.14198/jhse.2017.124.15
14. Jagiello W, Jagiello M, Kalina RM, Barczynski BJ, Litwiniuk A, Klimczak J. Properties of body composition of female representatives of the Polish national fencing team - the sabre event. *Biology of Sport*. 2017;34(4):401-406. https://doi.org/10.5114/biolsport.2017.70526
15. Czajkowski Z. From agility to corporative abilities. *Sport Wyczynowy.* 1993; 18: 3-4 (in Polish)
16. Manolaki VG. *Teachers monitor the level of preparedness of skilled wrestlers on stage sporting perfection*. [PhD thesis]. Moscow; 1990. (In Russian)
17. Jagiello W, Wolska B, Sawczyn S, Dornowski M. The similarity of training experience and morphofunctional traits as prediction criteria of the sports level in subsequent stages of long-term women's judo training. *Archives of Budo*. 2014;10.
18. Todorow AS. *Control coordination movements of freestyle wrestlers*. [PhD thesis]. Moscow; 1991. (In Russian)
19. Lee KM. *Taekwondo kyorugi: sports combat training.* Centralny Ośrodek Sportu; 1998. (In Polish)
20. Romanenko V, Podrigalo L, Iermakov S, Rovnaya O, Tolstoplet E, Tropin Y, et al. Functional state of martial arts athletes during implementation process of controlled activity - comparative analysis. *Physical Activity Review*. 2018;6:87-93. https://doi.org/10.16926/par.2018.06.12
21. Bujak Z. Differences in the level of selected elements of motor coordination among taekwon-do contestants at unsophisticated and masterly level. *Movement Coordination in Team Sport Games and Martial Arts*. 1998: 25-28. (In French)
22. Volodchenko OA, Podrigalo LV, Iermakov SS, Zychowska MT, Jagiello W. The Usefulness of Performing Biochemical Tests in the Saliva of Kickboxing Athletes in the Dynamic of Training. *Biomed Research International,* 2019:2014347. https://doi.org/10.1155/2019/2014347
23. Sadowski J. Studies of selected elements of movement coordination in taekwondo athletes. *Rocz. Nauk. IWFiS.* 1999; 5: 37-40.
24. Pietrow AM. *Central programs are the mechanisms for implementation of coordinating sportsmen's methods and their pedagogical skills*. [PhD thesis]. Moscow; 1997. (in Russian)

Information about the authors:

Zeghari L.; (Corresponding author); https://orcid.org/0000-0001-6769-6864; zegharilotfi@gmail.com; Royal Institute of Management training, National Center of Sports Moulay Rachid, Salé; National Center of Sports Moulay Rachid, Road of Meknes Km 12, Salé, Morocco.

Moufti H.; http://orcid.org/0000-0001-6421-1454; h_moufti@yahoo.fr; Royal Institute of Management training, National Center of Sports Moulay Rachid, Salé; National Center of Sports Moulay Rachid, Road of Meknes Km 12, Salé, Morocco.

Arfaoui A.; http://orcid.org/0000-0002-5705-2536; amine_arfaoui@yahoo.fr; Royal Institute of Management training, National Center of Sports Moulay Rachid, Salé; National Center of Sports Moulay Rachid, Road of Meknes Km 12, Salé, Morocco.

Gaidi A.; https://orcid.org/0000-0002-0037-4657; gaidiabdoujudo@gmail.com; Royal Institute of Management training, National Center of Sports Moulay Rachid, Salé; National Center of Sports Moulay Rachid, Road of Meknes Km 12, Salé, Morocco.

Addal K.; https://orcid.org/0000-0001-8995-5417; khadija.addal1997@gmail.com; Royal Institute of Management training, National Center of Sports Moulay Rachid, Salé; National Center of Sports Moulay Rachid, Road of Meknes Km 12, Salé, Morocco..

Cite this article as:
Zeghari L, Moufti H, Arfaoui A, Gaidi.A, Addal K. Impact of coordination training on the development of speed among young judokas from 10 to 12 years old. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2019;23(6):325-329.
https://doi.org/10.15561/18189172.2019.0608

Received: 07.08.2019
Accepted: 25.07.2019; Published: 30.09.2019

SUBMISSION OF MANUSCRIPTS

(For more detailed information see http://www.sportpedagogy.org.ua/index.php/PPS/pages/view/trebovaniya-e)
Structure of article:
- title of an article;
- surname, full first name and patronymic;
- full name of organization (place of work or study);
- annotation in three language (Russian, Ukrainian, English). The scope of the annotation is to be 800-1000 symbols.

Annotation must contain translate of surname, full first name and patronymic of authors, in Ukrainian (Russian) and English. Structure of annotation: *Purpose, Material, Results, Conclusions*. For authors from Russia, the translation in the Ukrainian language makes editorial board.

Key words for the three languages: (4-6 words).

Introduction

Hypothesis, Purpose

Material and methods

Participants.
Research Design.
Statistical Analysis

Results
Discussion
Conclusions
Conflict of interests
References (more than 20) should be making up according to standard form.

REVIEW PROCEDURE FOR MANUSCRIPTS (For more detailed information see https://sportpedagogy.org.ua/index.php/PPS/pages/view/recenzirovaniye-e)
All manuscripts submitted for publication must go through the review process.
TREATMENT OF MANUSCRIPTS (For more detailed information see https://sportpedagogy.org.ua/index.php/PPS/pages/view/rassmotreniye-e)
Manuscripts are assessed by the Editorial Board within 1 month.
The Journal will acknowledge receipt of a manuscript within 2 days.
EDITORIAL ETHICS (For more detailed information see https://sportpedagogy.org.ua/index.php/PPS/pages/view/ethics-e)
The journal is committed to a high standard of editorial ethics.
Editorial board is used the principles of ethics of scientific publications upon recommendations of International Committee of Medical Journal Editors.
Conflicts of interests of persons who have direct or indirect relation to the publication of an article or any information that the article consist are settled according to the law of Ukraine in the field of intellectual property.

CONTACT INFORMATION
box 11135, Kharkov-68, 61068, Ukraine
phone. 38-099-430-69-22
http://www.sportpedagogy.org.ua
e-mail: sportart@gmail.com

Information Sponsors, Partners, Sponsorship:

- Olympic Academy of Ukraine
- Ukrainian Academy of Sciences.

SCIENTIFIC EDITION (journal)
Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports. 2019;23(6)
----
designer: Iermakov S.S.
editing: Yermakova T.
designer cover: Bogoslavets A.
administrator of sites: Iermakov S.S.
____
passed for printing 30.09.2019
Format A4.
Red Banner str., 8, Kharkov, 61002, Ukraine.
PRINTHOUSE (B02 № 248 750, 13.09.2007).
61002, Kharkov, Girshman, 16a.