

## IMPACT OF OVERHEAT ON DISABLED SWIMMERS' SKELETAL MUSCLE STIFFNESS

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**Annotation.** Contemporary athletic recovery involves the range of treatments combined with training and restitution processes and are designed to optimize rest as well as minimize the effects of sports overstrain. Sportsmen benefit enormously from recovery treatments during both preparation and competition phases as they help remove frequent pathogenic pre-start conditions which could reduce work capacity and affect adversely results achieved. *Purpose:* The paper is aimed to specify the impact of overheat on easing the stiffness of disabled sportspeople's biceps muscle of arm and the central part of the deltoid muscle. It has been assumed that overheating in a Finnish sauna will facilitate muscle condition and recovery of a swimmer's body. *Material:* The research involved 20 disabled swimmers – 10 competitors based in the Start sports club in Kalisz and 10 contestants based in Start sports club in Wrocław. The Tonus-1 myotonometer was used to measure the stiffness of biceps muscle of arm (*biceps brachii*) and the central part of the deltoid muscle (*deltoideus – pars acromialic*). The research was carried out in two stages: training mesocycle with no recovery and training mesocycle with recovery. The mesocycles comprised three one-week-long microcycles each. *Results:* The research proved the overheating to ease rest muscle stiffness. *Conclusions:* The upshot of the discussion was that the Finnish sauna has a tonic effect on a disabled swimmer's body. Reduction of post work-out muscle stiffness will facilitate effective recovery and bring forward next training activities.

**Keywords:** *recovery, Finnish sauna, disabled sports, swimming, muscle stiffness.*

### Introduction

In their pursuit of achieving best results sportspeople will use drugs and food supplements to increase their physical capacity (Birch et al., 2008; Bird et al., 2005; Hass et al., 2000). Dry and humid heat play an important role in body recovery treatment (Adams et al., 1960; Chevront et al., 2001; Febbraio, 2001). Sauna proves advantageous in sports and physical exercises in many ways. It provides a good solution for a warm-up – raises body temperature, stimulates blood circulation and metabolic processes Kauppinen et al., (1986) – eases muscles, prevents and treats muscle injuries, enhances the circulatory system (Prystupa et al., 2009; Hopman, 1994), facilitates post work-out mental recovery and rapid weight loss Gutierrez et al., (2003), helps acclimatise to hot weather conditions (Yamaski et al., 2001), Gleeson, 2001). Massive body exposure to high temperatures in a sauna will enhance blood circulation and ensure extraordinary muscle recovery. Hot air and stimulating cold baths taken alternately provide perfect relaxation for a sportsperson's mental recovery, which by all means contributes to faster and more enjoyable physical rejuvenation (Czerkowski et al., 1996; Smolander, 2002; Noakes, 2000; Adams et al., 1960).

**Material and methods:** The research involved 20 disabled swimmers – 10 competitors, aged 14 – 25 years, based in the Start sports club in Kalisz and 10 contestants, aged 13 – 28 years, based in Start sports club in Wrocław. All of the them were verified in compliance with *General Medical Classification for Disabled Sports*. The group of Wrocław swimmers included three with leg amputation, one suffering from paraplegia, two from various locomotor system diseases and four with cerebral palsy. The Wrocław swimmers included two suffering from vision impairment, two with leg amputation, two suffering from various locomotor system diseases and four with cerebral palsy. The Tonus-1 myotonometer was used to measure the stiffness of biceps muscle of arm (*biceps brachii*) and the central part of the deltoid muscle (*deltoideus – pars acromialic*) measured at rest and under maximum tension Simons and Mense (1999). The research was carried out in two stages: training mesocycle with no recovery and training mesocycle with the recovery. The mesocycles comprised three one-week-long microcycles each. Statistika (9 StatSoft) was applied for statistical computations. Arithmetic means ( $\bar{x}$ ), standard deviations ( $s$ ) and variation coefficients ( $v$ ) have been calculated. Statistical significance between the two groups' means was estimated with the Student's test ( $t$ ), and in case of more than two groups involved ANOVA one-way analysis of variance with replications was used.

**Results:** The research showed that the stiffness of the biceps muscle of arm at rest after the training was substantially higher than before in the training mesocycle with no recovery (stage 1) (Table 1, 2, Fig. 1). The training mesocycle with the recovery (stage 2) is marked with much lower stiffness of the biceps muscle of arm at rest before the training and after, upon the exit from sauna. Admittedly, however, significant outcome was reported only after the training for the Kalisz swimmers while in case of the Wrocław group notable results were revealed both before and after the training strain.

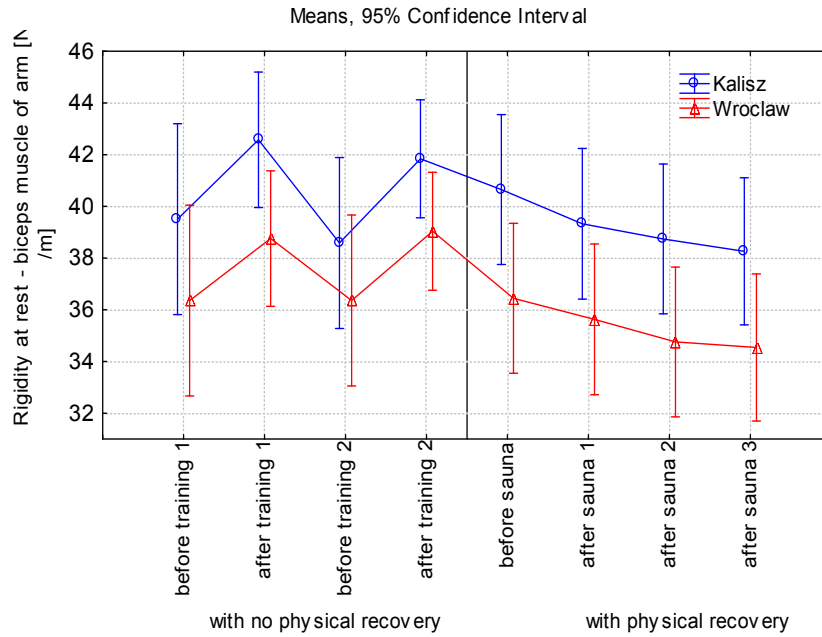


Figure 1. Stiffness differences in the biceps muscle of arm at rest for disabled swimmers in the training cycle without and with physical recovery<sup>2</sup> Measurements biceps stiffness at rest:  $F(7, 126) = 79568, p = 59228$

According to the assessment of the central part of the deltoid muscle for both clubs swimmers, the stiffness at rest in the training mesocycle with the recovery (stage 2) is substantially reduced before and after the training, upon the exit from sauna (Table 1, 2, Fig. 2). Stiffness parameters compared before and after the mesocycle training failed to prove statistically significant differences for the Kalisz swimmers while in case of Wroclaw competitors notable changes were recorded.

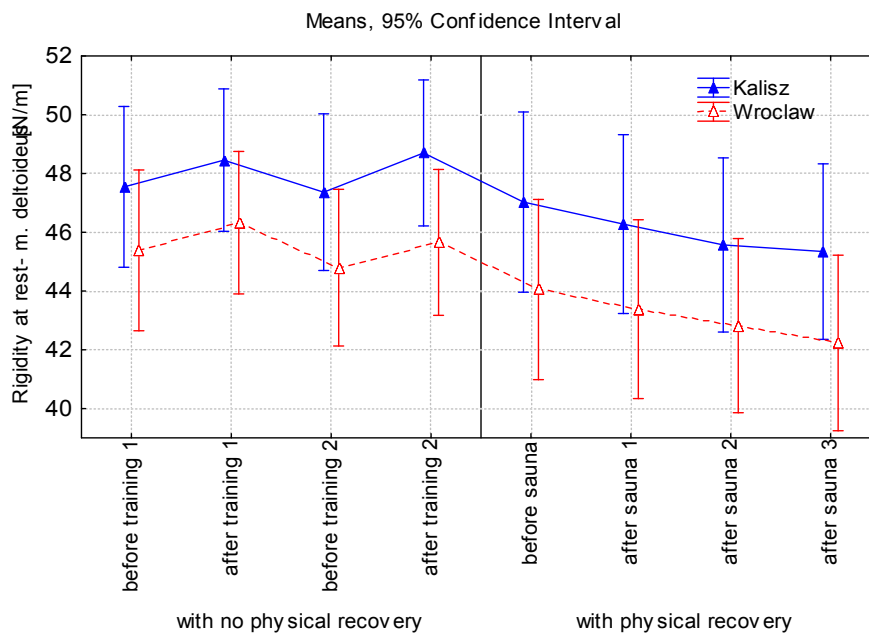


Figure 2. Stiffness differences in the deltoid muscle at rest for disabled swimmers in the training cycle without and with physical recovery Deltoid muscle stiffness measurements at rest:  $F(7, 126) = 38324, p = 91074$

Results for the deltoid muscle stiffness under tension before and after the mesocycle training with no physical recovery (stage 1) as well as upon the exit from sauna in the mesocycle training with the recovery (stage 2) prove insignificant (Table 1, 2, Fig. 3).

<sup>2</sup>Statistical significances are marked with braces.

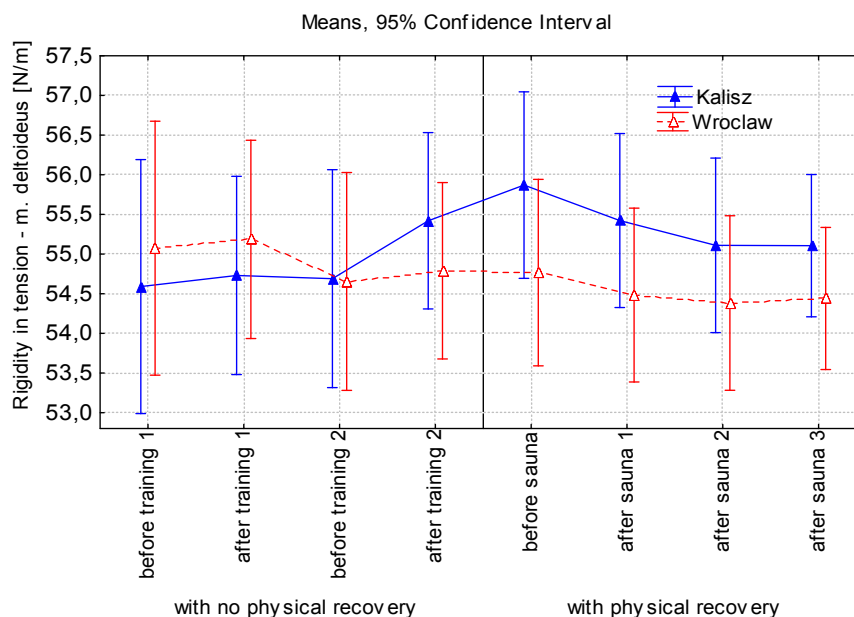


Figure 3. Stiffness differences in the deltoid muscle under tension for disabled swimmers in the training cycle without and with athletic recovery.

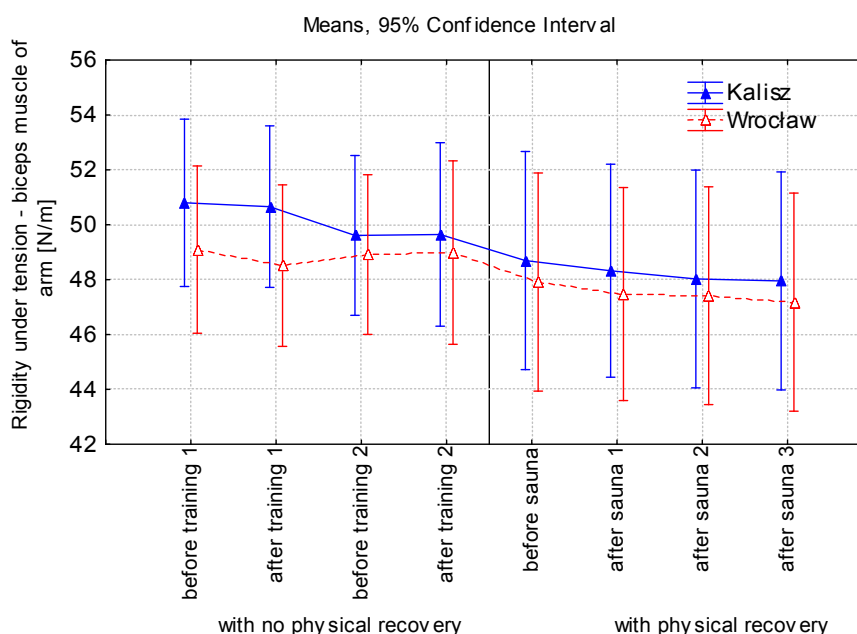


Figure 4. Stiffness in the deltoid muscle under tension for disabled swimmers in the training cycle without and with athletic recovery.

According to the research the stiffness parameters for a swimmer's biceps muscle of arm before and after the training session as well as upon the exit from sauna in the mesocycle with the recovery interrelate (Table 1, 2, Fig. 4). Such a relation was recorded for the swimmers based in Kalisz in the first week of the mesocycle with the athletic recovery. In case of Wrocław-based contestants, the interrelation between the parameters in the mesocycle with the recovery was disclosed only following the third sauna session. Stiffness parameters for a swimmer's biceps muscle of arm measured under tension before and after the training in the mesocycle with no recovery remain approximately at the same level for all the swimmers.

Table 1.

*Stiffness parameters for Kalisz-based swimmers in the training cycle with athletic recovery*

Muscle stiffness	Before training session – week 1 with sauna			After training session – week one with sauna			Before training session – week 2 with sauna			After training session – week 2 with sauna		
	I	II	III	I	II	III	I	II	III	I	II	III
biceps muscle of arm at rest	0.8125	0.3098	0.0995	<b>0.0000</b>	<b>0.0000</b>	<b>0.0000</b>	0.3247	0.8366	0.6656	<b>0.0011</b>	<b>0.0001</b>	<b>0.0000</b>
biceps muscle of arm under tension	<b>0.0048</b>	<b>0.0017</b>	<b>0.0013</b>	<b>0.0077</b>	<b>0.0028</b>	<b>0.0021</b>	0.1387	0.0685	0.0573	0.1283	0.0627	0.0523
deltoid muscle at rest	<b>0.0437</b>	<b>0.0019</b>	<b>0.0006</b>	<b>0.0006</b>	<b>0.0000</b>	<b>0.0000</b>	0.0828	<b>0.0046</b>	<b>0.0015</b>	<b>0.0001</b>	<b>0.0000</b>	<b>0.0000</b>
deltoid muscle under tension	0.0724	0.2604	0.2634	0.1342	0.4102	0.4143	0.1133	0.3629	0.3667	0.9942	0.5015	0.4969

Table 2.

*Stiffness parameters for Wrocław “START” Sports Club-based swimmers in the training cycle with athletic recovery*

Muscle stiffness	Before training session – week 1 with sauna			After training session – week 1 with sauna			Before training session – week 2 with sauna			After training session – week 2 with sauna		
	I	II	III	I	II	III	I	II	III	I	II	III
biceps muscle of arm at rest	0.3357	<b>0.0351</b>	<b>0.0170</b>	<b>0.0001</b>	<b>0.0000</b>	<b>0.0000</b>	0.3324	<b>0.0345</b>	<b>0.0167</b>	<b>0.0000</b>	<b>0.0000</b>	<b>0.0000</b>
biceps muscle of arm under tension	0.0627	0.0537	<b>0.0283</b>	0.2321	0.2064	0.1260	0.0974	0.0844	<b>0.0466</b>	0.0824	0.0711	<b>0.0386</b>
deltoid muscle at rest	<b>0.0016</b>	<b>0.0000</b>	<b>0.0000</b>	<b>0.0000</b>	<b>0.0000</b>	<b>0.0000</b>	<b>0.0250</b>	<b>0.0018</b>	<b>0.0000</b>	<b>0.0004</b>	<b>0.0000</b>	<b>0.0000</b>
deltoid muscle under tension	0.2006	0.1351	0.1698	0.1296	0.0838	0.1078	0.7096	0.5558	0.6410	0.5061	0.3783	0.4481

**Discussion:** The relation between the swimming training and the muscle stiffness at rest was proved. It has been recorded that the stiffness of the biceps muscle of the arm decreases in the training cycle with athletic recovery. It is worth noting that the Wrocław-based swimmers reported lower stiffness parameters for that muscle which could result from different individual training processes designed by the coach for each swimmer Atkinson and Reilly (1996), Andersen et al. (2005). Stiffness of the deltoid muscle at rest in the cycle with the recovery would decline, like for the biceps muscle of the arm. Stiffness of the deltoid muscle measured under tension failed to disclose any statistical validity which may indicate that the training process combined with the recovery has no major impact on the decrease of the muscle stiffness under tension Andersen et al. (2005), Drozdowski (1986). The deltoid muscle shows no statistically significant changes probably due to various muscles being involved in swimming depending on the style. Supposedly, other muscle examination might disclose more distinctive results. Strange as it may seem, in the first week of the training mesocycle with no recovery the stiffness parameters for the Wrocław-based competitors were recorded at the higher level. Nevertheless, only then the parameters turned out lower for the Kalisz swimmers. The research showed that the major muscle stiffness decrease in the cycle with the physical recovery was recorded following the first exit from sauna. The results indicate wave character of the changes of muscle stiffness in the training mesocycle with no athletic recovery (stage 1), that is to say, the stiffness parameters will always be lower before and higher after the training. Swimmers’ training, always tough and arduous, will shape various motoric skills depending on swimmer’s needs Steadward and Walsh (1986). Successful performance at the sports competitions is determined first and foremost by proper selection and execution of training load Hass et al. (2008), Kawakami et al. (1995). Swimming disciplines and the training are both likely to have a major impact on a competitor’s physiology, which is especially true in case of disabled sportspeople making even more effort to fight their dysfunctions. Sports training involves the whole range of physiological changes in a contestant’s muscular system Cheuvront and Haumes (2001). Training fatigue will intensify

the muscle stiffness, which, in turn, may result in minor overuse injuries and consequently to a major injury. Therefore it seems especially important to include the athletic recovery in the training schedules to monitor a sportsperson's body rejuvenation Coris et al. (2004). To avoid chronic fatigue sportspeople are more and more likely to take advantage of athletic recovery treatments. Well tailored and applied recovery helps mitigate fatigue and physical overstrain as well as speed up the preparation progress prior to the next competitions. Recovery monitoring and support account for an important element of training process for each athlete Prystupa et al. (2007), (2010). Training intensification, necessary to achieve the best results with no health damage, is only possible when the post work-out restitution accompanies the training activities. The intervention in the process of relaxation and body recovery must conform to modern solutions in effort physiology, psychology and training technology. It is also expected to refer to the state-of-the-art scientific technologies. Combination of training with athletic recovery will allow to enhance sports achievements on an ongoing basis, prevent excessive exhaustion and avoid muscle injuries Prystupa et al. (2006). Champion results are determined by the ability of a competitor's body to recover after each intensive training. Every coach should be aware of the limits of an exhaustive training and accept that excessive strain not only fails to bring expected extra results but also may have adverse effect on both physical and mental condition of their charges. Keeping on top form proves more difficult, contestants are exposed to overload, excessive fatigue and risk of injuries Kibier et al. (2002). According to the above careful approach to effective relaxation techniques and athletic recovery has been increasingly gaining importance Prystupa et al. (2006, (2010). The authors' own research confirm sports training's great influence on physiology and increased muscle stiffness which, in excess, may lead to major sports injuries Kibier et al. (1992). Therefore, providing that sports training has enormous impact on selected muscles, it must also affect the whole disabled swimmer's body. Effective rejuvenation therapy is quite likely to minimise the risk of injury. Competent and effective management of the training process is possible in the co-operation with doctors, physiologists and physiotherapists who can implement ongoing procedures and step-by-step effort capacity control. Swimmers injuries will result mostly from prolonged contact with chemically treated water and from excessive training Kibier et al. (1992), Bird et al. (2005). The research results indicate that Finnish sauna treatment decreases muscle stiffness at rest and has a tonic impact on the whole disabled swimmer's body. Minimising the post work-out muscle stiffness facilitates body recovery and brings forward the preparation to successive training sessions Atkinson and Reilly(1996), Rehunen (1988), Kukkonen-Harjula et al. (2006). Spinal cord injuries and following spasticity are the most common Prystupa et al. (2006). The research show that the muscle stiffness rises after the training in the mesocycle Uilmor and Kostill (1997), Ulatowski (1992). The phenomenon naturally results from increased muscle activity during exercising. Such activity may be exceptionally intense depending on the training. Simons and Mense (1999) claim that muscles hardly tolerate prolonged contractions or monotonous repeated movements. Excessive exposure to such conditions may bring adverse effects of muscle disorders and pain. Training process involves unlimited high intensity repetitions which leads to painful changes in muscle stiffness. Well-designed trainings accompanied by athletic recovery treatments will restore post training metabolic processes in the muscles and prevent undesirable body conditions Kibier et al. (1992), Ross and Leveritt (2001). According to the authors' measurements the Wrocław-based swimmers reported lower muscle stiffness parameters at rest, which indicates differences in the training approaches and in physical training effects. Drozdowski (1986) concludes that the research on muscle tension has been increasingly gaining interest. Muscle tension changes allow to identify the level of fatigue, exhaustion and the body's effort capacity. Admittedly, however, muscle tension may be a sign of some neurological changes caused by specific activity Sliwiński and Halat (2001). According to the research the surrounding temperature has a major impact on the muscle hardness. The above allows for the conclusion that the higher the temperature the softer the muscle and the other way round Drozdowski (1986), Gandel'sman (1976). According to Drozdowski (1986), muscle hardness and flexibility reflects the body capacity and its ability to take efforts of various kinds. The authors find physical effort linked to specific sports exercises increasing muscle hardness proportionately to the muscle volume and the intensity of the exercises Brooks (2003), Prystupa et al. 2010). Prolonged exercises tend to shape up muscle hardness characteristic to particular sports disciplines depending on the type of training (Platonow and Sozański (1991), Ronikier (2001). Szirmai myotonometric measurements confirm the objective qualities of the method as well as its capability to carry out the training cycle assessment. Moreover, the non-invasive and pain free method may be applied regardless the conditions. Myotonometric assessment of disabled swimmers' muscle stiffness is quite rare in sports trainings therefore the publications on sauna's impact on the stiffness remain limited. Any initiatives to conduct related research and control the training process most effectively should be encouraged ( Ronikier 2001).

#### **Conclusion:**

1. Training mesocycle with the athletic recovery in a Finnish sauna reduces the muscle tension at rest.
2. Muscle stiffness parameters at rest are significantly lower compared to respective parameters measured under tension.
3. In most cases muscle stiffness at rest is higher after than before the training.
4. Muscle stiffness change dynamics during the training mesocycle with no recovery has wave character; the parameters rise and decline alternately.
5. Falling muscle stiffness parameters upon the exit from sauna – overheating stage – was recorded in all the cases.
6. Due to the type of their dysfunctions, training load and their ability to maintain general fit body condition, disabled swimmers require rejuvenation treatments supporting training processes.

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