ORIGINAL ARTICLE

The effect of a placebo on strength performance in children

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

Abstract

Background and Study Aim: Placebo responses are a well-known psychophysiological phenomenon observed in various areas of human performance. In the context of physical activity, these responses can influence motivation, perceived exertion, and measurable motor outcomes in both adults and children. Although placebo strategies are used in different practical settings, their relative effectiveness in enhancing strength performance in children remains a subject of practical interest. This study examined the impact of placebo administration on strength-related outcomes in children.

Material and Methods: Ninety-two participants (mean age 10.4 years) were randomly assigned to a placebo group (n = 47) or a control group (n = 45). The placebo group received a sweet-tasting liquid accompanied by a verbal suggestion of performance enhancement. Performance was assessed using a pull-up hold, handgrip strength, a wall-sit hold, and the standing broad jump.

Results: Within-group analyses showed improvements in both groups for the pull-up hold (Control: $p = 0.044$, $d = 0.39$; Placebo: $p < 0.001$, $d = 0.42$). Only the placebo group showed significant gains in right-hand grip strength (+2.8 kg, $p < 0.001$, $d = 0.73$), left-hand grip strength (+2.0 kg, $p < 0.001$, $d = 0.57$), and the wall-sit hold (+21.3 s, $p = 0.001$, $d = 0.52$). Between-group comparisons showed significant advantages for the placebo group in right-hand grip strength ($p < 0.001$, $d = 0.79$) and in the standing broad jump ($p = 0.008$, $d = 0.58$). There were no significant differences in the other outcomes.

Conclusions: The findings indicate that placebo interventions in children may preferentially enhance strength-endurance tasks, with less consistent effects on explosive performance. The improvement in handgrip strength, particularly in the right hand, suggests that placebo mechanisms may also influence measures of maximal strength.

Keywords: fitness, exercise, placebo effect, children, strength

Introduction

Placebo responses represent a complex interaction of psychological and physiological mechanisms that can shape human performance across a wide range of activities. In the field of pediatric physical activity, these responses may influence how children perceive effort, respond to physical tasks, and regulate their motor behavior. Strength-related performance in childhood is affected by multiple factors, including motivation, expectations, and situational cues, which makes the study of placebo mechanisms particularly relevant. The role of placebo administration in this context helps clarify how children's performance outcomes unfold in controlled settings.

The placebo effect is defined as "an intervention capable of influencing the organism's functioning despite lacking the inherent potential to produce such effects" [1]. It arises not from the treatment itself but from the psychosocial context in which it is delivered. Verbal suggestions, environmental cues, or sensory characteristics (e.g., taste, color, packaging) shape expectations and conditioning processes, producing measurable physiological and psychological outcomes [1, 2]. Neurobiological studies show that placebo interventions can activate endogenous opioid, cannabinoid, and monoaminergic systems, along with conditioned immune and endocrine responses [3, 4]. Functional neuroimaging implicates the prefrontal cortex, anterior insula, and nucleus accumbens in these processes [5, 6]. Conditioning appears to produce stronger and more sustained effects than expectancy alone in both pharmacological and nonpharmacological contexts [7, 8, 9].

In exercise science, the placebo effect is highly relevant due to its link with fatigue perception and motivation. Fatigue can be viewed as a protective emotion, shaped not only by metabolic limits but also by central regulation of effort [10]. Central governor models suggest that the brain integrates metabolic, sensory, and psychological inputs to preserve homeostasis [11]. Placebo interventions may act as cues that reduce central inhibition and enhance motor output. Evidence from adult populations indicates that placebo effects on strength performance can range from 3.1% to 19.7%, with relative improvements generally

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greater in strength than in endurance tasks [12, 13, 14, 15].

Children appear particularly susceptible to placebo effects, with reviews and meta-analyses consistently reporting higher response rates than in adults, while pharmacological treatment effects remain similar across age groups [16]. Elevated placebo responses have been observed in pediatric depression, epilepsy, and migraine [17, 18, 19]. Pooled analyses suggest rates of 50–60% in children with psychiatric disorders, compared with 30–40% in adults [20]. Explanations include greater learning capacity, sensitivity to suggestion, parental expectations, and contextual influences such as therapeutic contact or media exposure [21, 22].

Despite evidence for higher placebo responsiveness in children across clinical contexts, its potential impact on strength performance remains largely unexplored [23]. Previous pediatric studies have focused mainly on endurance-related outcomes, while research involving neuromuscular tasks consists of isolated findings without consistent patterns [24, 25, 26]. For example, Fanti-Oren et al. reported placebo-related improvements in aerobic capacity [24, 25], whereas Stopper et al. described effects on enjoyment and overall activity, but without clear implications for objective strength measures [26]. Findings from adult research indicate that different manifestations of strength may vary in their susceptibility to placebo effects, with maximal strength and strength-endurance showing stronger responses than explosive power [12, 13, 14, 15].

Analysis of research findings has shown that placebo mechanisms can influence various components of physical performance, including motivation, perceived exertion, and motor output in both adults and children. Researchers emphasize that different manifestations of strength may respond unequally to placebo-related cues, and that children often display heightened sensitivity to contextual and psychosocial factors shaping their performance. These observations highlight the complexity of placebo responses in pediatric populations and point to unresolved aspects regarding their role in strength-related tasks. Taken together, these considerations create the basis for examining how placebo administration may influence strength performance in children.

Analysis of research findings has shown that placebo mechanisms can influence various components of physical performance, including motivation, perceived exertion, and motor output in both adults and children. Researchers emphasize that different manifestations of strength may respond unequally to placebo-related cues, and that children often display heightened sensitivity to contextual and psychosocial factors shaping their performance. Whether these mechanisms translate to prepubertal children remains unclear, given developmental differences in motivation, fatigability, and neuromuscular characteristics. In addition, no study to date has systematically examined whether different strength domains respond equally to placebo manipulations in children, leaving several aspects of placebo-related strength modulation unresolved. Taken together, these considerations create the basis for examining how placebo administration may influence strength performance in children.

This study examined the impact of placebo administration on strength-related outcomes in children.

Materials and Methods

Participants

Seventy-six healthy, prepubertal children without known health limitations, attending regular school and participating in physical education without restrictions, were recruited for the study. The sample consisted of 49 girls (mean age = 10.4 years, SD = 0.57, range: 9.5–11.6 years) and 27 boys (mean age = 10.8 years, SD = 0.63, range: 9.7–12.0 years). Participants were randomly assigned to either the placebo group (n = 47) or the control group (n = 29). Randomization was performed using a computer-generated sequence (Excel RAND function), and allocation concealment was ensured via sealed opaque envelopes opened only at the point of group assignment. Group sizes were not identical due to the randomization process and participant availability. After assignment, no participants crossed over. All analyses were performed on an intention-to-treat basis.

Written informed consent was obtained from all participants and their legal guardians before participation. The study protocol was approved by the Committee for Research Ethics at the University of Hradec Králové (approval number: 8/2023) and was conducted in accordance with the Declaration of Helsinki. A priori power analysis (G*Power) indicated that a minimum of 34 participants was required to detect medium effects (d = 0.5) with 80% power at $\alpha = 0.05$. The final sample met this requirement. Although the final allocation resulted in unequal group sizes, the achieved sample in both groups exceeded the minimum needed to detect medium effects, and all analyses were adjusted for unequal variances where applicable.

Study Design

This study employed a randomized, controlled, pre–post intervention design with a placebo group and a control group. Testing was conducted in small subgroups to ensure optimal supervision and

consistent measurement procedures. All assessments for pre- and post-intervention measurements were performed at the same time of day to minimize the influence of circadian variation. The study was conducted under single-blind conditions, in which participants were unaware of their group allocation, while the researchers were informed of the placebo administration to ensure correct implementation of the protocol. Blinding success was checked after testing by asking participants which drink (performance-enhancing or no drink) they believed they had received.

Intervention

A placebo intervention was used to induce performance-enhancing expectancies. The intervention was described to participants as a pre-workout supplement that typically enhances physical performance, increases strength, and delays fatigue (e.g., through ingredients such as caffeine). The placebo consisted of a commercially available sugar-free fruit syrup (Sunquick®, orange–mango flavor) diluted with carbonated water (ratio of 1:10) and served flavor-matched in standardized single doses of 60 mL in identical disposable paper cups. All beverages were freshly prepared following a written preparation protocol to ensure consistency in appearance, carbonation, smell, and taste across participants. The placebo was administered as a liquid, with the chosen volume corresponding to dosing used in comparable expectancy-based placebo protocols in children [24, 26].

Immediately before testing, the assessor delivered a standardized instruction to all participants: "This is a pre-workout supplement commonly used to improve physical performance. Its effects usually start within 2–5 minutes. Some people notice mild tingling in the muscles as it begins to work. It can help you be stronger and keep going for longer." The wording and timing were held constant across subgroups to minimize experimenter variation.

Standardized instructional script for placebo administration and strength testing

1. Pre-test general instructions (delivered to all participants)

"Today we will complete several short strength tests. Your task is to always try your best.

If anything feels uncomfortable or you want to stop, raise your hand. We will help you."

(Neutral tone; no mention of performance enhancement.)

2. Placebo administration script (placebo group only)

Hand-out statement. "This drink is a pre-workout supplement that many athletes use before exercise. It can help your muscles feel stronger and work for longer."

Expected sensation. "Its effects usually start within 2–5 minutes. Some people notice a light tingling feeling in the muscles when it starts working."

Instruction to consume. "Please drink the entire portion now. When you finish, place the cup on the table."

(Ensure full ingestion; visually check and confirm.)

Motivational yet neutral reinforcement. "Remember to always try your best in each test."

3. Control group instruction

"Today we will complete several short strength tests. Your task is to always try your best."

(Identical to pre-test general instruction; no supplementation and no expectancy cues.)

4. Allowed encouragement in testing (standardized phrases)

During tests, only neutral motivation was permitted: "Keep going.", "You're doing well.", "Stay steady.", "As long as you can.", "Keep your form." Disallowed: Any mention of improvement, superiority, or supplement effects; competitive language (e.g., "Beat your last score!").

Administration occurred just prior to the test battery (within the same session and at the same time of day as pre and post measurements for all participants) to align the suggested onset (2 to 5 minutes) with the start of performance testing. All testing was conducted in small subgroups under identical supervision and instructions. Participants were observed ingesting the full dose, and any incomplete ingestion would have been recorded, although none occurred.

Participants randomized to the control group completed the identical warm-up and test battery under the same environmental and scheduling conditions as the placebo group without ingesting any supplement or placebo beverage. No intervention or expectancy-inducing statements were provided at the post-test. At the pre-test, all participants, regardless of group allocation, were informed only that the purpose of the session was to assess their physical fitness. This standard information was delivered in a neutral tone and without reference to performance enhancement. No adverse events were reported or observed during or after ingestion.

Before the start of testing, all participants completed a 5 minute general warm-up consisting of light running combined with dynamic, multi-joint movements and mobility exercises targeting the major muscle groups and joints involved in the subsequent tests. The warm-up was performed at low to moderate intensity to prepare the musculoskeletal and cardiovascular systems without inducing fatigue. All participants performed the same standardized sequence under the supervision of the research team.

Outcome measures

The test battery was selected to assess multiple strength domains in prepubertal children: absolute strength, relative strength, muscular endurance, and explosive strength. All tests were performed in the same order for all participants to minimize fatigue bias and ensure consistent procedures. The sequence was as follows:

1. Handgrip strength
2. Pull-up hold
3. Standing broad jump
4. Wall-sit hold.

Standardized verbal instructions and demonstrations were provided before each test, and participants performed one familiarization trial when applicable. To ensure measurement standardization and minimize inter-rater variability, the same pair of trained assessors administered and scored all tests according to a written protocol, following identical criteria at both pre and post testing.

Handgrip strength. Absolute strength was measured using a calibrated hand dynamometer (Kern MAP 80K1S, Germany). Participants stood upright with the testing arm fully extended alongside the body without contact with the trunk. The handle position was individually adjusted to fit the participant's hand size. Each participant performed two maximal squeezes with each hand, alternating sides, with at least 30 seconds of rest between trials. The highest value for each hand was recorded for analysis.

Pull-up hold. Relative upper-body strength was assessed using a static chin-over-bar hold. Participants grasped a horizontal pull-up bar with a supinated grip at shoulder width and were assisted to the starting position with the chin clearly above the bar. Timing started when the participant was stationary in the correct position and ended when the chin dropped below the bar level. No kipping or leg assistance was allowed. Bar height was standardized at 1.80 m.

Standing broad jump. Lower-body explosive strength was evaluated using a two-footed horizontal jump from a standing position. Participants stood with their feet shoulder width apart behind a marked starting line. Using a two-foot takeoff, they were instructed to jump forward as far as possible while swinging their arms freely. Distance was measured from the starting line to the rearmost point of landing, usually the heels. Two trials were performed, and the longest valid jump was used for analysis.

Wall-sit hold. Lower-body muscular endurance was assessed using an isometric squat position held against a vertical wall. Participants positioned their back flat against the wall, knees flexed to 90°, hips also at approximately 90°, and feet flat on the floor at shoulder width. Arms were crossed over the chest to avoid support from the legs. Timing began when the participant achieved the correct position and ended when they could no longer maintain it, for example when joint angles changed or the hands left the chest. Joint angles were verified using a handheld goniometer before timing began, with positioning performed quickly and efficiently to avoid premature fatigue and any influence on subsequent performance.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics (version 29.0, IBM Corp., Armonk, NY, USA). The normality of change scores (post minus pre) was assessed separately for each outcome variable and group using the Shapiro–Wilk test. For normally distributed data ($p \geqslant 0.05$), paired-sample t tests were used to examine within-group changes. For non-normally distributed data ($p < 0.05$), the Wilcoxon signed-rank test was applied. Effect sizes for within-group comparisons were calculated as Cohen's d for paired samples and interpreted as small (0.2), medium (0.5), and large (0.8). Between-group differences in change scores (Δ = post minus pre) were evaluated using the Mann–Whitney U test. Between-group effect sizes were expressed as Cohen's d based on pooled standard deviations. Statistical significance was set at $\alpha = 0.05$, and exact p values were reported. Descriptive statistics are presented as mean ± standard deviation (SD). Raw data are available from the corresponding author upon reasonable request.

Results

Baseline and post-intervention descriptive statistics, p values for within-group changes, and effect sizes are presented in Table 1. In both the control and placebo groups, pull-up performance improved over the intervention period. The placebo group also showed increases in right-hand grip strength, left-hand grip strength, and wall-sit time, while the control group did not show changes in these measures. Jump performance did not show statistically significant change in either group, although a small negative effect appeared in the control group.

As shown in Table 1, both groups demonstrated improvements in some of the assessed strength measures. The placebo group showed positive changes across a broader range of tests, whereas changes in the control group were less consistent. Tasks requiring sustained effort appeared to show clearer improvement than explosive performance.

Between-group differences in change scores are illustrated in Figure 1. The placebo group exhibited more favorable changes in several strength measures, while other outcomes showed comparable patterns between groups.

Table 1. Pre- and post-intervention performance in strength tests

Test	Group	Pre-test mean (SD)	Post-test mean (SD)	p value	Cohens d
Pull-up hold (seconds)	Control	10.63 (11.15)	14.0 (11.17)	0.044	0.392
	Placebo	13.95 (12.35)	17.63 (14.18)	0.001	0.418
Handgrip right (kg)	Control	15.28 (1.02)	15.24 (1.26)	0.842	-0.037
	Placebo	14.55 (1.67)	15.3 (1.19)	0.001	0.728
Handgrip left (kg)	Control	14.81 (1.01)	14.93 (1.06)	0.424	0.151
	Placebo	13.99 (2.1)	14.6 (1.61)	0.001	0.566
Wall-sit hold (seconds)	Control	91.93 (72.62)	104.1 (67.87)	0.233	0.226
	Placebo	80.6 (67.26)	134.04 (121.65)	0.001	0.523
Standing broad jump (cm)	Control	129.52 (25.23)	125.79 (26.18)	0.071	-0.348
	Placebo	128.89 (27.17)	132.55 (28.16)	0.079	0.262

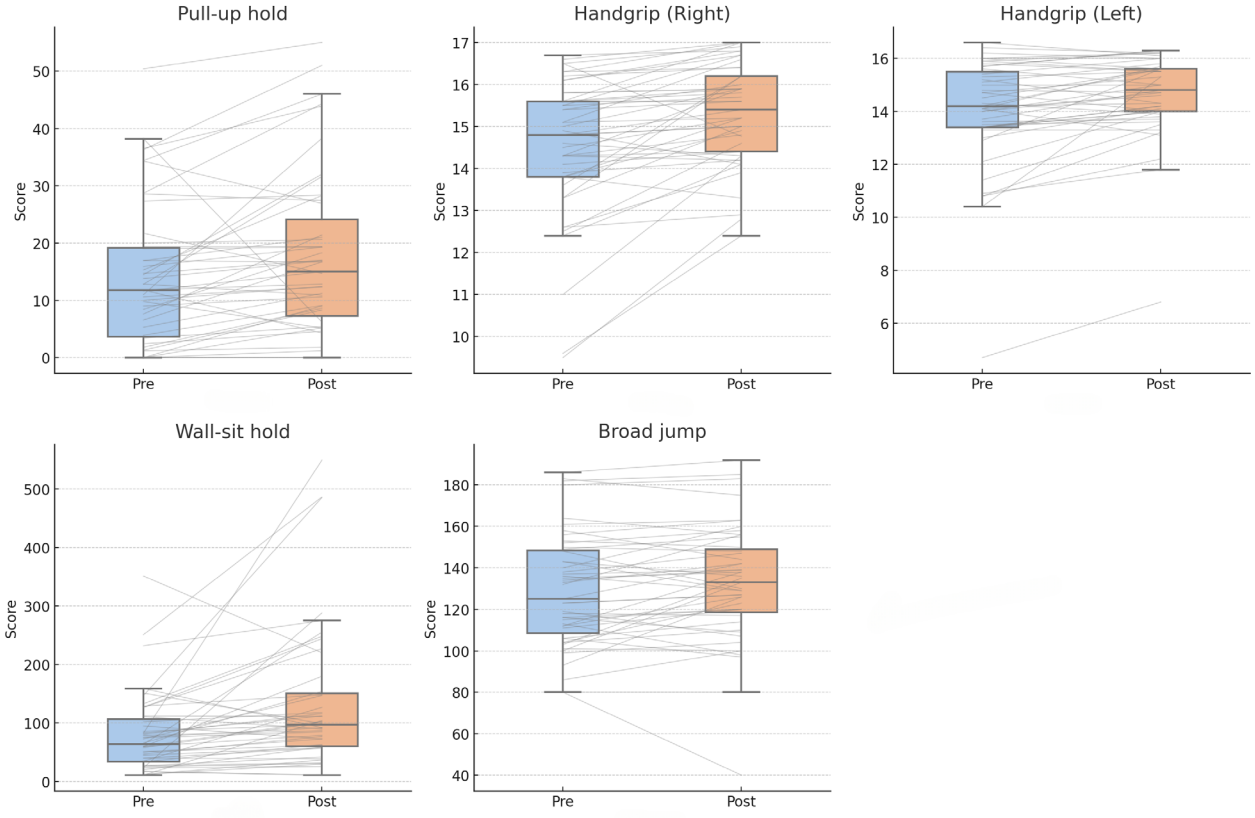

Figure 1. Pre- and post-intervention performance in the placebo group. Values are presented as boxplots with individual trajectories (gray lines) indicating pre–post changes for each participant.

Discussion

The present study examined the placebo effect on strength performance in children, focusing on tests representing maximal strength, strength endurance, and explosive power. The findings showed a placebo-induced improvement in right-hand grip strength and in wall-sit endurance. Pull-up performance improved in both groups. Jump performance did not show placebo-related gains. These results suggest that the placebo effect in children may influence tasks that require sustained muscular engagement. Its impact on explosive output appears more limited. This domain-specific variability aligns with adult research showing stronger placebo effects in strength and strength endurance than in explosive movements [12, 13, 14, 15] and extends this pattern into a prepubertal population.

Children's physiology provides an additional perspective. Compared with adults, they rely more heavily on aerobic metabolism, produce lower lactate concentrations, and have reduced glycogen storage capacity [27]. Muscle fiber characteristics also differ, which may lower sensitivity to local metabolic by-products that in adults contribute to perceived exertion and muscular discomfort [28].

These factors may explain why children experience different subjective sensations during muscular fatigue, similar to the attenuated delayed-onset muscle soreness observed in pediatric populations [29]. Consequently, placebo interventions may exert their strongest influence where central regulation of effort is the primary limiting factor, as in strength endurance tasks.

The contextual design of placebo delivery is especially relevant in pediatric populations. Previous studies used visually salient or symbolic carriers, such as flavored liquids presented in specialized containers [24, 25, 26], or everyday objects such as a "tic-tac" pill [30]. The role of the administrator, whether a researcher in a white coat or a familiar adult, may also shape children's expectations and reinforce perceived efficacy. Narrative framing, such as presenting the placebo as a "magic potion" [26], can further increase suggestibility. In our study, it is plausible that both the delivery method and the information provided amplified the children's belief in the intervention and contributed to the observed improvements. In contrast to some of these approaches, our study used a standardized expectancy induction protocol and controlled the context of administration. This approach allowed a more precise interpretation.

An additional factor to consider is that the placebo substance used in this study had a sweet taste. Even non-caloric sweet solutions can elicit physiological and metabolic responses similar to those induced by sugar-containing drinks [31]. Sweetness has also been shown to influence cognitive functions, which may in turn affect performance in strength-related tasks [32, 33]. On the other hand, administering a purely inert and tasteless fluid might have raised suspicion among participants and reduced the credibility of the intervention.

Placebo effects are closely linked to learning mechanisms in which conditioning and expectation interact [7]. In children, these mechanisms may be shaped not only by direct experience but also by observation and social modeling. Although participants in this age group often lack prior exposure to ergogenic supplements, they may still associate external substances with performance enhancement through observation of adults, media representations, or the symbolic role of medications and stories. This sensitivity to suggestion may explain the placebo responses reported in pediatric populations [16, 21]. Our findings support the idea that children's expectations can alter their physical performance, although with variability across task demands.

Not all studies have confirmed the presence of significant placebo effects on muscular strength. No improvements were observed in maximal strength or strength endurance during the bench press [13], and no significant placebo effect was detected in handgrip strength in children [26]. Studies by Fanti-Oren et al. showed placebo-related improvements mainly in aerobic endurance tasks [24, 25], while Stopper et al. reported effects on enjoyment and general activity rather than objective neuromuscular outcomes [26]. Our results add to these findings by showing that placebo mechanisms can extend beyond endurance measures to specific strength domains in prepubertal children. This pattern supports the idea that different manifestations of strength, such as maximal, endurance, or explosive performance, may vary in their susceptibility to placebo mechanisms.

When interpreting the present findings, the role of test–retest reliability in pediatric populations should be acknowledged. In our data, some individuals showed considerable fluctuations between measurements, including unexpected declines in performance. These changes may reflect variability rather than true changes in ability. Previous research indicates that the reliability of field-based fitness tests in children varies across test types, with some assessments such as the standing long jump showing only moderate reliability [34]. More broadly, reliability in pediatric field testing is influenced by the nature of the task, the testing protocol, and the developmental stage of the participants [35]. These aspects highlight the need for cautious interpretation of both improvements and declines in performance, as they may reflect limitations of the testing procedures rather than genuine training or placebo effects.

Significant improvements in handgrip strength were observed in both hands within the placebo group, although only the right hand showed an advantage compared to the control group. This pattern suggests that placebo responses may extend to measures of maximal strength, but their detectability may depend on effect size and variability across limbs [36]. The possibility that limb dominance could moderate placebo responsiveness was considered, but the improvement in both hands indicates that this factor is unlikely to be the sole explanation. The results support the interpretation that placebo effects in children's physical performance are mediated mainly through central motivational pathways rather than direct neuromuscular enhancement. The findings contribute empirical evidence clarifying which aspects of neuromuscular performance are most sensitive to expectancy-driven influences in youth.

Limitations of the study

The present study has several limitations. First, it did not compare children of different ages, which limits conclusions about developmental differences in placebo responsiveness. Second, testing was conducted in small groups rather than individually, which may have influenced motivation and performance. Finally, the placebo drink had a sweet

taste, and although sugar-free, such solutions can elicit physiological and cognitive responses beyond expectancy alone.

Future studies should examine developmental aspects of these mechanisms by comparing prepubertal and postpubertal children, as morphological, physiological, and psychological differences are likely to moderate placebo responsiveness. Experimental manipulations of delivery format, verbal suggestion, and contextual cues are also needed to clarify the relative contribution of expectancy, conditioning, and social modeling.

Conclusions

This study shows that placebo interventions can enhance selected strength outcomes in children, with improvements observed in grip strength and in strength endurance tasks. Effects on explosive performance were less evident. These findings suggest that placebo responses in pediatric populations operate mainly through motivational and expectancy-related mechanisms, although task-specific factors may modulate their impact. The results highlight the role of psychosocial context in children's exercise performance and indicate the need for further research into developmental differences and delivery methods to clarify the scope of placebo effects in this age group.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

AI tools usage

During the writing of this manuscript, the authors used ChatGPT (OpenAI, San Francisco, CA) to assist with language and grammar. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the final version of the publication.

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