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Effects of a minimal dose of plyometric training on the FITescola®

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ARMANDO COSTA[1], RAFAEL REIMANN BAPTISTA[2], CLARISSA BIEHL PRINTES[1,3], PAULO MALICO SOUSA[1,4], VALTER PINHEIRO[1,4], RAYNIER MONTORO-BOMBÚ[1,5]

[1] ISCE – Polytechnic University of Lisbon and Tagus Valley, Department of Sport Sciences, Lisbon, Portugal
[2] School of Medicine, Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, Brazil
[3] Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil
[4] Live Quality Research Center (LQRC), Complexo Andaluz, Santarém, Portugal
[5] University of Coimbra, Research Unit for Sport and Physical Activity (CIDAF), Faculty of Sport Sciences and Physical Education, Coimbra, Portugal

ABSTRACT
Purpose. The FITescola® was designed to promote physical activity and healthy lifestyle habits, as well as to assess the neuromuscular fitness determinants to know the motor habits of Physical Education students in Portugal. However, to date, it is unclear how a neural training programme can affect FITescola® activities. This study aimed to examine the effects of a Minimal Dose of Plyometric Training (MDPT) on the results obtained from the FITescola® test in adolescents between the ages of 11 and 13 years.
Methods. Eighty students were recruited for this study and randomly divided into two groups: an experimental group (EG-P = 40) and a control group (CG = 40). The EG-P underwent a reduced plyometric training programme (PTP), while the CG continued their physical education classes systematically without any specific plyometric intervention. Before and after the programme, the 40 m sprint (V40), standing long jump (SLJ) and 4 × 10 m agility (AG4X10) were assessed.
Results. The results showed significant group × time interactions for all variables, including SLJ [$F(1,73) = 13.72$, $p < 0.001$, $\eta^2 p = 0.158$], AG4X10 [$F(1,73) = 29.31$, $p < 0.001$, $\eta^2 p = 0.286$], and V40 [$F(1,73) = 8.85$, $p = 0.004$, $\eta^2 p = 0.108$], indicating that performance changes differed between the experimental and control groups.
Conclusions. Our results suggest that MDPT may be an effective and time-efficient strategy to improve neuromuscular performance in school-age students. Therefore, its inclusion in physical education classes may be beneficial provided that the training guidelines described in this study are followed.
Key words: plyometric training program, neuromuscular fitness, jumping test, sprinting test, agility test

Introduction

In sports training, there is a growing interest in optimising training stimuli through a minimal dose approach, to minimise the physical effort of athletes. This approach allows athletes to actively participate in training sessions and competitions with an optimal balance between efficiency and fatigue [1, 2]. Researchers have explored this concept, recognising that a minimal dose is a specialised program that does not adhere to established guidelines regarding volume, intensity, density, frequency, etc., but still has the potential to improve physical fitness [3, 4]. Consequently, minimal training doses can be easily adapted to contexts where variables such as available time for the activity, training space, material conditions and physical readiness of the practitioner do not meet previously established standards [3, 5].

The concept of minimal-dose training has already been explored in other domains, especially in resistance training [4, 6, 7]. Previous studies have demonstrated that minimum or low-volume resistance training protocols can lead to significant improvements in muscle strength and functional outcomes, even with markedly

Correspondence address: Armando Costa, ISCE – Polytechnic University of Lisbon and Tagus Valley, Department of Sport Sciences, Lisbon, Rua Bento de Jesus Caraça, 12, 2620-379 Ramada, Portugal, e-mail: armando.costa@isce.pt; https://orcid.org/0000-0003-2037-3771

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reduced time commitment [3, 4, 8, 9]. However, little attention has been given to the application of this concept to plyometric training, particularly in school-age populations [10]. This gap in the literature underscores the relevance of investigating minimal dose plyometric training (MDPT), especially in educational contexts, where logistical constraints are common.

In the school context, especially during early adolescence (11–13 years), a period commonly associated with accelerated neuromuscular development [11–13], the concept of a minimal dose becomes even more important. Previous studies have shown that 81% of adolescents between 11 and 17 years do not meet recommended physical activity levels [14, 15], which is in line with data from Portugal, specifically with regard to the development of neuromuscular fitness [16]. Additionally, school settings are characterised by heterogeneous student populations, often including individuals with low physical fitness and poor adherence to physical activity [15, 17]. This presents a challenge to educators who aim to improve neuromuscular qualities in students and ensure maximum stimulation in a short time.

In this sense, the use of MDPT, when implemented using a structured and pedagogically appropriate approach, may represent a viable strategy to enhance the efficiency of physical education. This may support the development of positive attitudes towards exercise, potentially facilitating long-term adherence, and contribute to the development of neuromuscular function, which is crucial for coordination, agility, and the reactive component of the stretch-shortening cycle (SSC) [18]. Therefore, for the purpose of this study, the MDPT was operationally defined a priori as a structured plyometric intervention characterised by: (i) a session duration of ≤ 15 min, (ii) the use of two plyometric exercises per session, (iii) ≤ 55 ground contacts per session, (iv) a training frequency of three sessions per week, and (v) a total intervention period of six weeks. This operational definition was established to clearly differentiate MDPT from previously described low-volume plyometric protocols, which typically involve longer session durations, greater numbers of exercises, and substantially higher ground contact volumes.

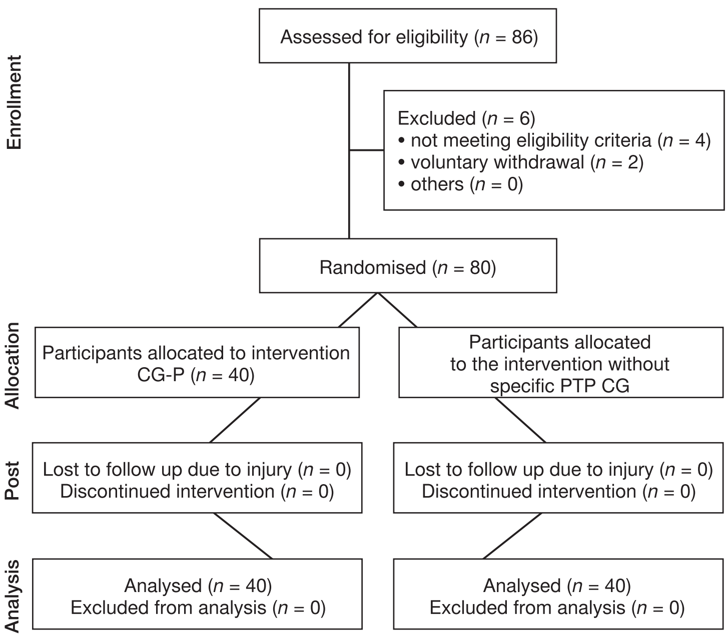
In Portugal, the FITescola® (fitescola.dge.mec.pt) [19] programme was developed to promote physical activity and healthy lifestyle habits among school-age children, while also serving as a tool to assess various domains of physical fitness. Among its components, neuromuscular fitness tests include the standing long jump (SLJ), the 4 × 10 m agility (AG4X10), and the 40 m sprint (V40). The SLJ evaluates lower-limb power through horizontal jumping performance; the AG4X10 test assesses agility and change-of-direction speed; and the V40 captures sprinting speed over a linear distance. These tests are particularly relevant for assessing neuromuscular fitness in adolescents, as they are practical, field-based, and sensitive to training-induced adaptations. Despite their inclusion in the national curriculum, the extent to which these tests can be improved through targeted neuromuscular training interventions such as MDPT has not been fully established.

To improve neuromuscular capacity, it is important to perform exercises that challenge the SSC. Plyometric training programmes (PTP) exploit the SSC by coupling rapid eccentric muscle actions with subsequent concentric contractions, thereby enhancing force production, motor unit recruitment, and neuromuscular efficiency [20, 21]. In youth populations, SSC-based training has been shown to improve explosive strength, sprint performance, and change-of-direction ability through neural adaptations such as improved intermuscular coordination and increased rate of force development [21]. Research also highlights the role of SSC training in optimising tendon stiffness and neuromechanical efficiency, which may contribute to improvements in athletic performance and movement economy [20].

Most of the plyometric research that found positive results with children and adolescents has presented interventions with a high degree of similarity in terms of the overall design of the training process and followed previously established recommendations regarding volume and intensity [5, 22]. For example, in boys, the effectiveness of different strength training methods (traditional training, PTP compared with combined training) over 6 weeks has been compared [23]. It was found that PTP was more effective than traditional or combined strength training in achieving short-term gains in sprinting and jumping parameters. In that study, the training sessions lasted no more than 60 min. Interestingly, similar results were observed when the total duration of the PTP session was less than 60 min [24]. The authors found a greater effect on the participants' sprint times when compared by growth velocity peak groups (pre-, mid- and post-ones). They determined that the combined PTP methods were the most effective in post-Growth Velocity Peak participants. Similarly, when comparing untrained and trained children, it was noted that the untrained participants benefited most from power training compared to traditional strength training in the parameters of running and jumping speed, showing large vs. moderate improvements in running time [25, 26]. Other studies have compared the effect of low and high-volume plyometric training on prepubescent soccer players over an

8-week period, with sessions held twice a week. After 8 weeks, the authors reported similar improvements in jumping ability between the two groups, suggesting that low-volume training is more beneficial from a time-efficiency perspective [27]. In light of the findings, it is recommended that a total session duration of more than 30 min and a training period between 6 and 10 weeks be observed in order to achieve positive effects in PTP [23, 25, 28]. However, it should be noted that these recommendations may not align with the total time available in the physical education curriculum, as lessons typically last 50–60 min and must cover various program contents.

A review of the literature indicates that in athletic training contexts, minimal doses (short durations, low volumes) have been shown to effectively increase strength, particularly in beginners compared to experienced individuals [3, 29]. However, the concept of MDPT has not been fully explored. Our review did not uncover any proposals of MDPT or studies demonstrating positive effects with reduced PTP of 10 to 15 min in the available literature. Specifically, no studies have shown positive effects on the SLJ, AG4X10, and V40 tests, neuromuscular fitness tests that are part of the FITescola® battery of tests [19]. Addressing this gap may provide a relevant framework for physical education teachers seeking time-efficient training strategies. Currently, there is limited evidence on the effects of MDPT can have on physical education students. Additionally, the potential benefits of PTPs lasting less than 10–15 min are not well established. Therefore, the aim of this study was to examine the effects of MDPT on the results obtained in the FITescola® neuromuscular fitness test.



Material and methods

Research design

A randomised pre-post experimental design was employed to analyse the effects of MDPT on the results of the FITescola® neuromuscular fitness test, namely the SLJ, AG4x10, and V40 tests. The training intervention (MDPT vs control condition) was defined as an independent variable, while the performance outcomes (SLJ, AG4X10, and V40) were treated as dependent variables.

The participants were randomly assigned to either the experimental group (EG-P = 40) or the control group (CG = 40) using a computer-generated randomisation sequence generated via an online randomisation tool (http://www.jerrydallal.com/random/randomize.htm). A simple randomisation procedure was applied. Outcome assessors were not blinded to group allocation due to the nature of the school-based intervention. Due to the nature of the intervention, allocation concealment was not implemented. The EG-P underwent MDPT consisting of a 6-week intervention with a frequency of three times per week and training sessions lasting only 10 to 15 min each. Meanwhile, the CG continued their physical education classes, but without any specific plyometric intervention. Specifically, both groups shared the same school context, were taught by the same physical education teacher, followed an identical curricular structure and lesson planning, and were exposed to comparable session duration and overall workload. In order to eliminate potential learning effects that could confound the study results, a familiarisation week was performed, following previous recommendations [30]. Before and after the intervention, SLJ, AG4X10, and V40 tests were performed. The tests were carried out in an indoor sports hall, always at the same time. All the training sessions took place during the first part of the Physical Education classes and lasted approximately 15 min after the general warm-up [30–33]. Figure 1 shows the flow of participants in each phase of the randomised trial.

Figure 1. The diagram (the CONSORT: consolidated standards of reporting trials) includes detailed information on the interventions received

Participants

A total of 86 individuals were recruited for the study, of whom 80 met the eligibility criteria (11 ± 1.8 years; height 148 ± 7.3 cm; body mass 41.57 ± 10.89 kg; BMI = 18.69 ± 3.58 kg/m^2). The sample included 46 boys and 40 girls. The inclusion criterion stipulated that all subjects must have attended Physical Education classes at least three times a week. Exclusion criteria included engagement in sports outside of school hours and/or injuries sustained within the past six months. During the intervention, students who missed more than 10% of the total MDPT sessions and/or more than three consecutive sessions were also excluded. As a result, participants included in the final analysis demonstrated a high level of adherence to the intervention (mean ± *SD*: 96.3 ± 2.1%). Prior to the commencement of the study, all participants and their legal guardians were thoroughly informed about the testing and training procedures, as well as the potential benefits and risks associated with the study. Prior to the commencement of the experiment, verbal and written informed consent was obtained from the legal guardians, and assent was obtained from the children.

Procedures

Following a familiarisation period, anthropometric data were collected in a single session. Each participant's height was measured on a stadiometer (Bodymeter 206, SECA, Hamburg, Germany) with an accuracy of 0.1 cm. Body mass was measured on a scale (SECA scale, Hamburg, Germany) with an accuracy of 0.1 kg. Body mass index was subsequently calculated according to previous recommendations [34]. Prior to the assessment protocol (SLJ, AG4X10, and V40,), the athletes underwent a standard warm-up consisting of a 10-minute period of running at a self-selected comfortable pace, followed by 5 min of calisthenics exercises and mobilisation of the principal joints. After 5 min of recovery period, measurements were obtained, and all tests were conducted in accordance with the FITescola® test guidelines.

40-meter sprint

The experiment was conducted in an indoor sports hall, with the timing of the sprints being recorded using photocells (Microgate, Bolzano, Italy), positioned at 0.15 m before the start line and 0.20 m above ground level. The start of the race was standardised for all participants, with three points of support being provided. Each athlete began the race individually, without any verbal encouragement, thus ensuring that reaction time was not a contributing factor to the recorded times. Each participant completed two attempts, separated by a three-minute recovery period, as per previous studies [25]. The best of the two attempts was recorded for data analysis.

Standing long jump (SLJ)

The experiment was conducted in an indoor sports hall. All participants stood behind a line with their feet separated to the width of their shoulders, and they performed a powerful horizontal push with their arms free. Each athlete executed two SLJ attempts, with a recovery period of approximately one minute between each attempt. Performance was measured using a 50-meter tape measure (Metal Works, Concesio, Italy), with the final footprint left by the athlete used as the reference point. For data analysis, the maximum distance achieved in the two jump attempts was documented.

Shuttle run (AG4X10)

The space was marked by signalling cones, and two parallel lines 10 m apart were indicated with adhesive tape. Three sponges were utilised in this experiment: two sponges (A and C) were positioned on the line opposite the starting line, and the third sponge (B) was placed on the starting line. The sponges, A and C, were placed 1 m from each other. Participants were instructed to assume a standing start position behind the designated starting line. Upon the auditory signal, they sprinted with maximum expediency to sponge A, crossed the line with both feet, grasped sponge A, and returned to the starting line. Thereafter, sponge A was substituted for sponge B at the starting line, and the student traversed the line with both feet, reversing direction towards sponge C. After exchanging sponge B for sponge C and crossing the line completely with both feet, the student returned to the starting line. The temporal measurement was automatically halted when the student crossed the finish line with a single foot, holding sponge C in their hand. The temporal measurements were recorded using photocells (Microgate, Bolzano, Italy), which were positioned at a height of 20 cm above ground level.

Plyometric training programme

The GE-P group performed a MDPT consisting of pogo jump on stairs (PJmE) and tuck jump (TJ) exercises as summarised in Table 1. The PJmE exercises were executed on a 10-step staircase (4.80 m length, 40 cm width). The participants were instructed to land with their legs together on each step while ascending the staircase and, when reaching either end of the staircase, to perform a countermovement squat to approximately 90° knee flexion with their legs apart. The TJ was performed at a standardised intensity, requiring participants to jump over an elastic rope positioned at a height of 0.80 m after stepping off 0.30 m platform. Given the participants' untrained status, training volume and intensity were carefully controlled to ensure safe and consistent execution. Additional details regarding volume, frequency, and ground contacts are presented in Table 1.

Table 1. Minimal dose plyometric training programme

Variable	Description
Duration per session	≤ 15 min
Frequency	3 sessions/week
Intervention length	6 weeks
Exercises	PJ + TJ
Sets	3 sets per exercise
Repetitions	10 (PJ), 8 (TJ)
Ground contacts/session	≤ 55
Total contacts/week	162

PJ – pogo jump on stairs, TJ – tuck jump

Statistical analyses

Data are presented as mean ± standard deviation (*SD*). Additional data are presented as *p*-values ($p < 0.05$), confidence interval (*CI*) and effect size (*ES*). Normality was assessed using the Shapiro–Wilk test and homogeneity of variances using the Levene's test. No formal correction for multiple comparisons was applied due to the limited number of a priori-defined outcomes. An independent sample *t*-test was used to compare the participants' characteristics (between groups at baseline). To determine the effects of the intervention on performance adaptations, a two-way repeated-measures ANOVA (group × time) was conducted for each variable (AG4X10, V40, and SLJ). Main effects (group and time) and interaction effects (group × time) were analysed. Effect sizes for the ANOVA were calculated using partial eta squared (η^2p). Potential alterations in performance were interpreted using standard thresholds for η^2p (small = 0.01, medium = 0.06, large = 0.14). The α level was set at $p < 0.05$ for statistical significance. An a priori power analysis was conducted using G*Power software (version 3.1; Heinrich-Heine-Universität Düsseldorf, Germany) for a repeated-measures ANOVA with a within-between interaction (group × time). Assuming a medium effect size ($f = 0.25$), an alpha level of 0.05, a statistical power of 0.95, two groups, and two measurement time points, the required total sample size was estimated at 54 participants. The data were analysed using the Project Jamovi (2022) statistical programme (Version 2.3 of the computer software).

Results

Table 2 shows the mean ± *SD* data of AG4X10, V40, and SLJ in both groups at pre-test and post-test. No significant differences were observed between groups for any of the baseline variables ($p > 0.05$), confirming initial group equivalence. We found a significant main effect of time for SLJ, $F(1,73) = 4.33$, $p = 0.041$, $\eta^2p = 0.056$, as well as a significant group × time interaction, $F(1,73) = 13.72$, $p < 0.001$, $\eta^2p = 0.158$, with no significant main effect of group, $F(1,73) = 1.51$, $p = 0.223$, $\eta^2p = 0.020$. For AG4X10, no significant main effect of time was observed, $F(1,73) = 3.58$, $p = 0.062$, $\eta^2p = 0.047$, although a significant group × time interaction was found, $F(1,73) = 29.31$, $p < 0.001$, $\eta^2p = 0.286$, with no significant group effect, $F(1,73) = 1.43$, $p = 0.236$, $\eta^2p = 0.019$. Similarly, for V40, neither the main effect of time, $F(1,73) = 0.727$, $p = 0.397$, $\eta^2p = 0.010$, nor the main effect of group, $F(1,73) = 2.45$, $p = 0.122$, $\eta^2p = 0.033$, reached statistical significance; however, a significant group × time interaction was identified, $F(1,73) = 8.85$, $p = 0.004$, $\eta^2p = 0.108$.

Table 2. Descriptive statistics of neuromuscular performance variables in the experimental and control groups at pre-test and post-test

	Pretest (mean ± *SD*)	Post test (mean ± *SD*)	%	Pretest (mean ± *SD*)	Post test (mean ± *SD*)	%
AG4X10 (s)	13.07 ± 1.374	12.76 ±1.250	–2.38	12.91 ± 1.099	13.55 ±1.030	4.73
V40 (s)	7.39 ± 0.790	7.18 ± 0.711	–2.85	7.49 ± 0.871	7.60 ± 0.676	1.45
SLJ (cm)	144.95 ± 23.234	154.18 ± 23.458	5.99	145.11 ± 19.556	142.51± 18.945	–1.79

AG4X10 = 4 × 10 m agility test, V40 – 40 m sprint, SLJ – standing long jump

Discussion

To the authors' knowledge, this is the first study that examines the effects of a MDPT on the results obtained in the FITescola® neuromuscular fitness test. The study primary findings indicated that following the intervention, significant group-time interactions were observed in the AGX10, V40, and SLJ tests. The minimal dose design was defined based on a program duration of ≤ 15 min, ≤ 55 ground contacts per session, two exercises per session, a duration of six weeks, and a constant level of intensity. Specifically, the MDPT involved a weekly volume of ≤ 45 min and 162 ground contacts, while maintaining the same exercises per session and a constant level of intensity. Over the 6-week intervention, the total program volume was approximately 270 min, with a total of 972 ground contacts. These findings may be applicable to similar youth populations within school-based or structured training environments where supervised plyometric interventions can be implemented. In particular, the observed improvements in neuromuscular performance suggest that MDPT may represent a practical and time-efficient strategy in physical education and early-stage youth sport settings.

Previous studies have applied a PTP based on what they considered to be a low training volume [35]. In a PTP conducted with young soccer players, low volume was defined as an 8-week program with two sessions per week, progression from 50 ground contacts to 120 contacts per exercise, with a total of 4 exercises per session and session durations of 25 to 35 min [33]. This low volume differs from our minimal dose concept, as the weekly and total volume values in terms of the duration of PTP implementation per session and the number of ground contacts were much higher than ours. The recorded values were: 50 to 70 min of PTP per week and 440 to 960 ground contacts per week, depending on the week (440 for the first two weeks, 528 for the third week, 520 for the fourth week, 660 for the fifth week, 780 for the sixth week, 800 for the seventh week, 960 for the ninth week), with total PTP volumes of 400 to 560 min and 5128 ground contacts [33]. Additionally, a similar PTP was applied to young soccer players, differing only in the number of exercises per session, which was reduced to one exercise [36]. A comparison of the weekly and total values obtained with those recorded in our study reveals that the total weekly volume of PTP and total application time were consistently higher than those implemented in the present study (50 to 70 min and 400 to 560 min, respectively). The number of ground contacts per week was lower during the initial 4 weeks (from 110 to 130) but higher in the subsequent weeks (from 165 to 240), while the total volume of ground contacts remained greater than in our MDPT protocol (1284 vs. 972 contacts). In a plyometric training protocol in a school environment, the authors considered a PTP with exercises progressing from low to high intensity and complexity. However, in contrast to the present study, the number of exercises per session was 12 to 14, and included, in addition to plyometric exercises, physical conditioning exercises, as well as speed and agility exercises at the end of the session [37], resulting in a substantially greater overall training volume and complexity compared to the MDPT approach. Taken together, these findings indicate that previously described low volume PTP protocols still involve considerably higher training loads than those applied in the present study, reinforcing the distinctiveness of the MDPT concept.

Although our conception of the minimal dose differs from that of previous studies, our research revealed a significant group × time interaction for SLJ, indicating that the improvement observed in the experimental group differed from the control group. The magnitude of this effect ($\eta^2 p$ = 0.158) suggests a moderate-to-large practical impact, supporting the effectiveness of the MDPT intervention. Given that both groups were exposed to identical physical education conditions, including the same teacher, lesson structure, and overall training load, the MDPT intervention represented the only systematically controlled difference between groups. Under these conditions, it is reasonable to interpret the observed improvements as primarily attributable to the MDPT rather than to external factors associated with regular physical education activities. Although the influence of uncontrolled variables cannot be entirely excluded in school-based settings, the consistency of the group × time effects supports the role of the intervention as the main driver of the observed adaptations.

This finding aligns with previous research reporting significant enhancements in SLJ performance following 8 weeks of plyometric training interventions (SLJ: Δ = 9.3%, *ES* = 1.1) [33, 38, 39], as well as moderate improvements (Δ = 4.2% [40] and increases of up to 7.3% following longer-duration protocols [41]. In addition, studies comparing the effects of low- and high-volume plyometric training in young population have reported similar improvements in jumping ability, suggesting that lower training volumes may be sufficient from a time-efficiency perspective [27]. In a school context, significant improvements in SLJ have also been observed following plyometric interventions (7.9 ± 17.3 cm vs. –0.3 ± 8.4 cm) [37].

However, it is noteworthy that the aforementioned studies, despite utilising a reduced training volume, involved a higher number of jumps than our own, except for the initial week of the PTP. The range of jumps per training session varied from 60 to 90 jumps [38], progressing from 50 to 120 jumps [33, 39]. Conversely, in the context of low volumes of PTP, a small effect size (*ES* = 0.32) was observed in the long jump test following the implementation of a PTP in conjunction with a low-volume change of direction training protocol, spanning a duration of six weeks, in young soccer players [42]. Moreover, a moderate effect size was evident in the long jump (*ES* = 1.0) among young soccer players. It is acknowledged that the observed variations in effect size may be attributable to the limited trainability of the sample. It is noteworthy that gains evident in a small to moderate effect size are typically observed in elite athletes, resulting in comparatively smaller magnitude increases [3, 29]. In the context of physical education, the implementation of MDPT may be particularly advantageous, as it optimises time efficiency, reduces mechanical load, and prioritises movement quality over training volume, making it well-suited for school-based settings.

Previous studies have shown significant improvements in change of direction after 8 weeks (Δ = 2.1%; $d = 1.3$, $p < 0.05$). Additionally, when comparing high intensity and low volume (60 jumps) over 7 weeks, significant improvements in agility test performance were found (Illinois test, Δ = 3.5 %, *ES* = –0.28) [43]. With a similar protocol, it was found that after 12 weeks the results obtained in agility were higher (Δ = 3.3%, *ES* = 1.8) [44]. On the other hand, when comparing low- and high-volume plyometric training protocols to improve the agility in prepubescent footballers, it was concluded that there were no significant differences between the different types of the program, both of which showed significant improvements in the agility of the players ($p = 0.002$, *ES* = 0.96) [27]. The results suggest that increasing the volume of plyometric training is not a determining variable for improved agility performance, and that protocol-related differences may influence the outcomes.

When we analysed the results of the AG4X10 test, we found that the experimental group achieved significant improvements in reducing the agility test time (–2.38%), unlike the control group, which showed a worsening of performance (+ 4.73%). These changes were supported by a significant group × time interaction, indicating that the evolution of performance differed between groups. This reduction in the experimental group may be associated with improvements in the SSC, which enhances the speed of muscle contraction and reaction time [8]. Our results are in line with previous studies using low-volume plyometric training that reported significant improvements (–0.23 s) in 6 weeks [31] and 9.6% (–0.45 s) in 8 weeks [31]; 9.6% (–0.45 s), in 8 weeks [9]. It can therefore be suggested that a minimal dose approach may be sufficient to elicit meaningful improvements in neuromuscular performance of school-age children.

Regarding speed, several studies suggest that PTP improves this capacity in young athletes [45–48]. In line with this finding, our study supports the idea that MDPT can be a valid proposal to include in physical education classes. When analysing the V40 results using a repeated-measures approach, a significant group × time interaction was observed, indicating that performance changes differed between groups. Post-intervention, improvements were observed in the experimental group (7.39 ± 0.790 s pre-intervention to 7.18 ± 0.711 s post-intervention) whereas no significant changes were observed in the control group (7.49 ± 0.871 s pre-intervention to 7.60 ± 0.676 s post-intervention). The data suggest that the observed improvements in speed performance may be due to central nervous system factors such as increased muscle stimulation and trainability induced by PTP. These include the ability to increase the number and/or firing frequency of active motor units [49], changes in motor unit recruitment patterns and a particular emphasis on type II (fast twitch) muscle fibres [50]. In addition, the improvement in speed performance may be associated with an increase in strength, particularly maximal muscle strength, thereby enhancing acceleration capacity.

Our findings are consistent with previous studies reporting improvements in speed following plyometric training. For example, studies using high-volume plyometric training protocols in young athletes have shown significant improvements in sprint performance. A high-volume protocol (3 sessions per week, progressing from 100–200 to 300–360 jumps) applied over 10 weeks resulted in improvements of approximately 3% in 20-m sprint performance [51]. Similarly, another study investigated the effects of a high-volume plyometric training protocol (2 days per week, 112–350 jumps) over 16 weeks in young footballers and reported significant improvements in sprint times over a range of distances (5 m: Δ = 3.8%, *ES* = 1.3; 10 m: Δ = 2.2%, *ES* = 1.06;

20 m: Δ = 3.2%, *ES* = 0.8; 30 m: Δ = 2.5%, *ES* = 1.43) [41]. In contrast to other studies, when a short-duration, low-volume PTP was applied, significant reductions in the 10 m sprint time (–2.1%) were found [9]. The PTP led to a significant decrease of 2.1% (1.96 ± 0.07 to 1.92 ± 0.07 s; p = 0.004) in the sprint time of the experimental group, which was not seen in the control group (2.06 ± 0.12 to 2.01 ± 0.07 s; p = 0.15). Similarly, when studying the effect of low-volume PTP (60 to 120 jumps) twice-week for 12 weeks on the athletic ability of prepubescent male athletes (~11 years old), significant improvements were seen in sprint times (Δ = 5%, –3.5% and –3% for sprint times of 10 m, 20 m and 30 m, respectively) [40]. Similar results were found with a low volume, short duration plyometric training programme (from 50 jumps to 120, 2×/week, 8 weeks) [36].

From an applied perspective, the observed effect sizes (η^2p = 0.108–0.286) indicate meaningful and educationally relevant improvements within the constraints of school-based physical education. In settings where instructional time is limited and student populations are heterogeneous, even modest gains in neuromuscular performance may have substantial practical value, particularly when they can be achieved without compromising other curricular objectives. Importantly, the MDPT protocol required ≤ 15 min per session and a low number of ground contacts, demonstrating that measurable performance improvements can be obtained with minimal training exposure. This is particularly relevant in educational contexts, where time efficiency and feasibility are critical determinants of implementation. Under these conditions, the integration of MDPT does not appear to interfere with standard teaching practices but rather provides a complementary and scalable strategy to enhance neuromuscular fitness within existing class structures. Furthermore, given that both groups were exposed to comparable physical education conditions, the observed group × time effects reinforce the interpretation that the improvements are primarily attributable to the MDPT intervention rather than to general physical education activities.

However, the practical interpretation of these findings is inherently dependent on the reliability and sensitivity of the assessment tools used. Although SEM and MDC were not directly calculated in the present study, previously reported test-retest evidence indicates that the FITescola® battery and comparable field-based tests of standing long jump, sprinting, and agility show acceptable to good reliability in youth populations [19]. Therefore, the magnitude of the observed changes is likely to reflect real performance adaptations rather than only random measurement error.

There are some limitations to consider when interpreting this study. Firstly, due to time constraints, we were only able to include a limited number of tests from the FITescola® program; therefore, future research should aim to include a broader range of assessments. Secondly, although both groups were exposed to standardised physical education conditions under the same teacher and structured lesson plan, detailed documentation of the specific session content was not systematically recorded. Thirdly, it should be noted that maturation status (e.g., biological age or peak height velocity) was not directly assessed in this study. Given the well-documented influence of maturation on neuromuscular performance and training responsiveness in youth populations, this factor may have affected the observed adaptations [52]. Although randomisation likely contributed to a similar distribution of maturation status between groups, future studies should include objective measures of biological maturation to better control for its potential confounding effects. While this may represent a limitation, the controlled teaching environment likely minimised variability between groups. Fourthly, the inclusion of a group performing a higher-volume PTP could have provided a more comprehensive comparison of training effects. Future studies are needed to determine whether MDPT produces similar adaptations in populations with higher performance levels and to explore the transferability of these findings to more specialised training contexts. Also, studies should determine SEM and MDC directly under the same testing conditions to strengthen the interpretation of performance changes.

Conclusions

In terms of practical implications, the implementation of MDPT offers a promising, low-cost strategy that physical education teachers can integrate into standard class time without the need for additional resources.

After examining the effects of MDPT on the results obtained in the FITescola® neuromuscular fitness test, the findings indicate that the inclusion of MDPT can lead to meaningful improvements in neuromuscular performance in school-age students. Specifically, significant group × time interactions were observed for the SLJ, AG4X10, and V40 tests, indicating that performance changes differed between the experimental and control groups. The most pronounced improvements were observed in the SLJ. The MDPT protocol was characterised by a short session duration (≤ 15 min), a reduced number of ground contacts (≤ 55), a minimum of two exercises per session, a six-week intervention period, and a consistent intensity level. Despite this reduced training volume (≤ 270 min and ≤ 972 contacts), significant performance adaptations were observed, highlighting the efficiency of this approach. These findings suggest that MDPT may be sufficient to elicit meaningful neuromuscular adaptations in school settings, particularly when training time is limited. MDPT can be adapted to different skill levels and resource availability, making it a scalable and inclusive strategy for diverse educational contexts. However, these findings should be interpreted within the context of the study design, and further research is warranted to confirm their applicability across different populations and training environments. Therefore, the inclusion of MDPT in physical education classes is recommended provided that the guidelines outlined in this study are followed.

Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki [53] and was approved by the ethics committee of ISCE - Polytechnic University of Lisbon and Tagus Valley, Department of Sport Sciences, 2620-379 Lisbon, Portugal (ISCE-CE002-2024).

Informed consent

Informed consent was obtained from all individuals included in this study.

Conflicts of interest

The authors declare no conflicts of interest.

Disclosure statement

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