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ORIGINAL ARTICLE

Effects of cause-based and effect-based motor instruction on six-minute walk and cooper test performance in adolescent female volleyball athletes

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ABSTRACT

Background: Instructional strategies influence motor learning during adolescence, but it remains unclear whether instruction focused on biomechanical causes of movement yields different functional outcomes from instruction focused on observable movement effects. Methods: A total of 184 adolescent female volleyball athletes (mean age 14.44 ± 1.71 years) were stratified by age category and randomly assigned to a cause-based instruction group or an effect-based instruction group. Participants completed the Six-Minute Walk Test (6MWT) and 12-minute Cooper test before and after a 7–10 day intervention period, during which training load remained unchanged. Results: The cause-based group showed a significant pre–post improvement in 6MWT distance. Change-score analysis revealed a greater improvement in the cause-based group than in the effect-based group for the 6MWT ($p < .001$, r = .223), whereas no between-group difference emerged for the Cooper test ($p = .134$, r = .112). Conclusions: Cause-based instruction was associated with a small-to-moderate short-term improvement in submaximal walking performance, with no clear transfer to endurance field performance. These findings suggest that directing attention to biomechanical causes of movement may support functional motor organisation in adolescent athletes.

Keywords: Physical education, Motor learning, Attentional focus, Biomechanics, Sports performance.

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INTRODUCTION

The quality of the explanation provided by the teacher represents an important factor in motor learning, particularly during adolescence, when movement control processes remain sensitive to instructional approaches (Haibach-Beach et al., 2024). In educational contexts, a common teaching approach is based on the description of the visible effects of movement, whereby learners are guided to observe and reproduce the external form of the gesture (De Stefani et al., 2020; Wulf, 2012). This model, referred to here as effect-based instruction, relies primarily on the reproduction of observable movement features (Bach et al., 2024). Building on these considerations, the OPTIMAL Theory proposed by Wulf and Lewthwaite (2016) suggests that the way instruction directs learners' attention directly influences movement quality, learning stability and transferability across contexts (Song, 2019). Consistent with this perspective, research in motor learning has shown that skill acquisition is enhanced when attention is directed towards deeper and functionally relevant components of movement, such as its dynamics, generative forces and underlying muscular sequences (Pascua et al., 2015; Riemann & Lephart, 2002). This theoretical framework suggests that orienting learners' attention towards the components that generate movement, rather than solely towards its visible effects, may facilitate a more conscious and efficient construction of motor skills. At an educational level, this perspective also finds empirical support. De Oliveira et al. (2016) demonstrated that the quality and structure of information provided to learners influence perceived motor competence and movement organisation (Chambal et al., 2024). This indicates that not only what is taught, but also how motor content is presented, significantly contributes to the quality of learning. Similarly, Riskowski et al. (2013) highlighted that making cause–effect relationships explicit facilitates the identification of functional elements of movement and improves interpretative processes during observation. These considerations are particularly relevant when working with adolescent female athletes (Balyi & Hamilton, 2004; Lloyd et al., 2015).

Literature reports specific developmental trajectories in aerobic capacity, respiratory regulation and body perception in this population, often characterised by a relative slowdown compared with male peers after the onset of puberty (Malina et al., 2004; Armstrong & Welsman, 1997; Haapala et al., 2022). Furthermore, during the initial phase of the competitive season, movement organisation and functional efficiency may be especially sensitive to instructional modalities (Jelonek et al., 2017). In young athletes, physiological adaptations are responsive to variations in training load and to early preparatory phases, during which fluctuations in cardiorespiratory parameters may occur (Baxter-Jones & Maffulli, 2003; Migliaccio et al., 2023). However, it has not yet been investigated whether different instructional approaches, namely cause-based versus effect-based instruction, may influence standardised field-based functional indicators commonly used in physical education settings, such as walking performance tests (Troosters et al., 1999; Bohannon, 2018). Within this framework, growing interest has emerged in instructional approaches centred on the biomechanical generators of movement. In the present study, cause-based instruction was delivered through an experimental system designed to provide motor instruction based on explicit cause–effect relationships through guided visual and verbal explanations.

In light of these considerations, it appears relevant to examine whether an instructional approach centred on the generative biomechanical components of movement can produce measurable functional effects compared with an approach focused solely on observable outcomes. In the context of adolescent physical education, understanding the impact of instructional structure may help clarify the role of explanation in shaping movement organisation and functional performance quality. Therefore, the present study aimed to compare the effects of cause-based instruction and effect-based instruction on field-based functional indicators (Six-Minute Walk Test and Cooper test) in adolescent female athletes during the early phase of the competitive season.

METHODS

A total of 184 adolescent female volleyball athletes (mean age = 14.44 ± 1.71 years) participated in the study. All participants had been engaged in organised competitive training for at least three years within the organised youth volleyball system. They trained approximately four sessions per week (120–150 minutes per session) and followed comparable pre-season training schedules. All athletes were clinically healthy, free from musculoskeletal injuries at the time of testing and during the previous six months and were not taking any medication during data collection. In order to reduce potential hormonal influences, where feasible, participants were not assessed during the luteal phase of their menstrual cycle (Tenan et al., 2014; Sims & Heather, 2018).

The sample consisted exclusively of female adolescents to ensure homogeneity and reduce variability related to sex-based differences in physical development, strength and body composition (Armstrong et al., 2011). Body mass index (BMI) was recorded to verify baseline comparability between groups (overall mean BMI = 22.5 ± 2.5). Participants were allocated to two groups: Group 1 (experimental; n = 100; mean age = 14.41 ± 1.75 years), which received cause-based motor instruction, and Group 2 (control; n = 84; mean age = 14.48 ± 1.68 years), which received effect-based instruction. Stratified randomisation by age category (e.g., U14, U16) was performed using a computer-generated allocation sequence to ensure balanced distribution across age, training load and competitive level (Kernan et al., 1999).

Assessments were conducted following a two-month summer break, during the initial stage of the pre-season cycle. All athletes followed the same training programme under identical coaching staff and environmental conditions. The only difference between groups was the instructional modality applied during three instructional sessions delivered over a 7–10 day period. Data from four athletes were excluded due to absence during testing (n = 2) or injury (n = 2). Final analyses included only participants with complete T1 and T2 measurements. Pre-test (T1) assessments were conducted at the resumption of training, prior to the instructional intervention. Post-test (T2) assessments were conducted 7–10 days later, following three differentiated instructional sessions (cause-based vs. effect-based) while maintaining identical physical training loads. In Group 1, cause-based instruction was delivered through an experimental instructional system designed to provide biomechanically grounded explanations of movement through guided visual and verbal models.

The system emphasises generative forces, muscular sequencing and internal movement mechanics, encouraging deeper cognitive and proprioceptive engagement (see Table 1). In Group 2, effect-based instruction was delivered verbally by a single trained instructor using standardised technical cues focused on observable movement characteristics, such as segmental trajectories, limb positioning and rhythm (see Table 2). No explicit reference to internal biomechanical mechanisms was provided. Two validated field-based tests were selected: the Six-Minute Walk Test (6MWT) and the 12-minute Cooper test. The 6MWT was chosen to assess submaximal functional walking capacity and potential changes in functional movement organisation (Li et al., 2005; Geiger et al., 2007).

The Cooper test was used as a broader indicator of endurance field performance and functional endurance (Cooper, 1968). Both tests were administered on the same day under identical environmental conditions. The 6MWT was performed first, followed by the Cooper test after sufficient recovery, defined as the return of heart rate to individual baseline values (Bandyopadhyay, 2015).

Table 1. Operational summary of cause-based instruction on walking (Group 1).

Instructional phase	Delivered content	Perceptual focus	Biomechanical objective
Introduction to walking	Walking is a multisystemic and complex motor action involving muscles, joints, nervous system, and senses.	Global awareness of the body in motion	Understand walking as a coordinated outcome of multiple systems
Focus on movement initiation	The first step does not start from the leg swinging forward, but from the backward push of the rear limb.	Awareness of the posterior chain (glutes, hamstrings)	Highlight the invisible propulsive forces initiating movement
Posterior activation cue	Imagine your feet 'rowing' the floor backward to move forward	Focus on the rearward ground contact and propulsion	Engage glutes and hamstrings to generate the propulsion vector
Correction of common misconceptions	The movement doesn't start from the ankle or from pulling the leg forward	Eliminate perceptual illusions	Correct false motor representations
Guided practical experience	Walking uphill to feel clearer activation of the posterior chain	Distinction between what is seen and what is felt	Reinforce cause-effect connection through embodied learning
Symbolic anchoring	Like oars of a boat, your legs push backward to propel your body forward	Use of metaphor to guide motor focus	Integrate cognitive, perceptual and biomechanical understanding

Table 2. Operational summary of the effect-based instructional protocol (Group 2).

Instructional phase	Delivered content	Perceptual focus	Instructional objective
Movement form emphasis	Observe the rhythm and symmetry of the steps; maintain consistent limb movement.	Visual imitation of external form	Reinforce movement aesthetics and timing consistency
Foot rolling technique	Roll the foot from heel to toe in a fluid motion.	Awareness of foot contact pattern	Enhance step fluidity and walking efficiency through visible correction
Upper body posture	Keep the trunk upright and shoulders aligned while walking.	Postural alignment via observation	Guide external postural form
Step length and cadence	Try to maintain regular step length and tempo throughout the test.	Step symmetry and pacing	Promote rhythmic and coordinated gait
Correction by demonstration	Watch and repeat the correct walking model; mirror the instructor.	Visual mimicry	Facilitate learning via external modelling
Feedback based on outcome	You walked too slowly focus on increasing your step length.	Performance outcome	Provide correction through external results rather than internal cues

RESULTS

Statistical analyses were conducted using IBM SPSS Statistics (version 29.0). Normality of distributions was assessed using the Shapiro–Wilk test. Significant violations of normality were observed for most variables in both groups ($p < .05$), with the exception of the 6MWT in Group 1 ($p = .086$) and the Cooper test in Group 2 ($p = .242$). Consequently, non-parametric tests were applied for all subsequent analyses. To assess pre–post differences within groups, the Wilcoxon signed-rank test was applied. In Group 1, a statistically significant improvement was observed in the 6MWT, with a mean increase of +7.95 m from T1 (M = 723.65 m) to T2 (M = 731.60 m), $p < .001$. No significant changes were detected in BMI or Cooper test performance ($p > .05$). In Group 2, the Wilcoxon test revealed no significant differences between T1 and T2 in any of the measured variables (6MWT, Cooper test, BMI). Between-group comparisons at T1 and T2 were conducted using the Mann–Whitney U test. No significant differences were found at baseline (T1) or post-test (T2), confirming the initial comparability of the groups. To evaluate the intervention effect, individual change scores (Δ = T2 − T1) were calculated for the 6MWT and the Cooper test. Mann–Whitney U analyses demonstrated a significantly greater increase in Group 1 compared with Group 2 for the 6MWT (U = 5287.50, Z = 3.022, *p*

< .001, r = .223), indicating a small-to-moderate effect size. No significant between-group difference emerged for the Cooper test (U = 4748.00, Z = 1.50, *p* = .134, r = .112). A descriptive analysis of individual changes in 6MWT performance showed that 32% of participants in Group 1 increased their walking distance from T1 to T2, compared with 12% in Group 2. A decline in performance was observed in 2% of participants in Group 1 and 11% in Group 2 (see Table 3).

Table 3. Distribution of individual performance changes from T1 to T2.

Test	Group	Improved n (%)	Declined n (%)
6MWT	G1 (n = 102)	32 (31.4%)	2 (2.0%)
6MWT	G2 (n = 82)	10 (12.2%)	9 (11.0%)
Cooper	G1 (n = 102)	16 (15.7%)	4 (3.9%)
Cooper	G2 (n = 82)	9 (11.0%)	8 (9.8%)

DISCUSSION

The present study examined whether a cause-based instructional approach, centred on the biomechanical causes of movement, would produce different functional outcomes compared with a traditional effect-based approach focused on observable movement form. The findings indicate that cause-based instruction led to a significantly greater improvement in submaximal walking performance, as measured by the 6MWT, compared with effect-based instruction. Although the effect size was small to moderate (r = .223), the between-group difference in change scores suggests that the instructional modality may have contributed to the observed improvement. In relative terms, the improvement corresponded to approximately a 1.1% increase in walking distance over a short time frame without modifications to training load. In trained adolescent athletes, even small short-term performance changes may reflect alterations in motor organisation rather than conditioning effects. Therefore, the magnitude of change should be interpreted within the context of a brief, instruction-only intervention. Within-group analysis showed a significant increase in 6MWT distance only in the cause-based group, while performance remained stable in the control group. More importantly, the comparison of individual change scores confirmed that the improvement was significantly greater in the experimental group.

The descriptive analysis further supported this pattern, with a higher number of participants in the cause-based group showing performance improvements and fewer declines compared with the control group. This distribution strengthens the interpretation that the instructional approach influenced the direction of change at the individual level. The results align with the OPTIMAL theory (Wulf & Lewthwaite, 2016), which emphasises the role of attentional focus and motivational mechanisms in optimising motor learning (Wulf et al., 2012). By explicitly highlighting the internal causal mechanisms underlying movement, the cause-based approach may have facilitated a deeper cognitive representation of gait mechanics, leading to measurable functional gains in a low-intensity task such as walking.

Regarding the Cooper test, a small, non-significant between-group difference was observed (r = .112). The absence of significant within-group changes indicates that short-term instructional interventions may exert more immediate effects on submaximal functional tasks than on endurance performance requiring greater physiological adaptation. This distinction likely reflects the different determinants underlying the two tests. While the 6MWT is sensitive to subtle changes in movement economy and mechanical coordination, the Cooper test is predominantly influenced by cardiorespiratory capacity and metabolic adaptations. No significant changes were detected in BMI in either group, which was expected given the short duration of the intervention and the absence of modifications to training load.

The stability of these variables strengthens the interpretation that the observed improvements in walking performance were attributable primarily to instructional rather than physiological factors. The relatively short duration of the intervention was a deliberate methodological choice. The study was intentionally structured to isolate the instructional variable while minimising physiological adaptations related to training load. By maintaining identical physical workloads and limiting exposure to three instructional sessions, the aim was to examine whether a “*pure*” cognitive-motor effect of instructional framing could be detected independently of conditioning changes. Given that training load remained unchanged and the intervention was instructional rather than physiological, the absence of significant effects on the Cooper test is consistent with the study design.

These findings support the interpretation that cause-based instruction primarily modulates motor organisation rather than endurance conditioning within a short time frame. From a pedagogical perspective, emphasising the causal and biomechanical foundations of movement may enhance functional motor organisation in adolescent athletes. Walking, as a relatively low cognitive-load activity, may be particularly sensitive to subtle improvements in internal coordination and movement awareness, whereby small adjustments in movement organisation may translate into measurable performance gains.

Limitations

Several methodological choices, while appropriate for the study context, should be acknowledged as limitations. The intervention was limited to three instructional sessions delivered over approximately one week. This design allowed isolation of the instructional variable without interfering with pre-season training demands; however, it likely constrained the magnitude and stability of observable adaptations. Previous research suggests that educational and motor learning interventions require prolonged exposure to produce consolidated and transferable effects, particularly in youth sport contexts (Granacher et al., 2011; Behringer et al., 2011). Future studies should therefore consider longer intervention periods, structured follow-up assessments, and integration of instructional approaches within regular training cycles to evaluate retention and long-term transfer. Additionally, although statistically significant differences were detected between groups, the observed effect sizes were small to moderate. Caution is therefore warranted in generalising the findings, and replication across different sports and developmental stages would strengthen external validity.

CONCLUSIONS

The present study indicates that a cause-based instructional approach, centred on the biomechanical causes of movement, was associated with a statistically significant improvement in submaximal walking performance (6MWT) in adolescent female athletes compared with a traditional effect-based approach. The observed between-group differences in change scores suggest that directing attention towards the causal mechanisms underlying movement may enhance functional motor organisation, even in the absence of modifications to training load. However, the modest magnitude of the effects and the short duration of the intervention suggest that instructional modality alone may not be sufficient to generate broader physiological adaptations within a brief time frame.

In practical educational contexts, the present findings support considering the inclusion of biomechanically grounded explanations within motor teaching practices, particularly during adolescence, when cognitive engagement and movement representation remain highly adaptable. Future research should investigate longer instructional cycles, integration with practical training, and longitudinal follow-up to determine the stability and transferability of these effects across different tasks and developmental stages.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. A. F. contributed to the conceptualization of the study, literature review, methodological design and drafting of the manuscript. S. T. contributed to the methodological supervision, research design, interpretation of findings, and critical revision of the manuscript. I. P. contributed to the technical and digital aspects of the study, including support for tool development and implementation and data analysis. L. C. contributed to the scientific supervision of the project, theoretical framing, interpretation of findings, and critical revision of the manuscript. All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

Participation was voluntary and preceded by signed informed consent from athletes and their guardians. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

ETHICAL CONSIDERATIONS

The study procedures adhered to internationally recognised ethical standards for research involving human participants and were conducted in accordance with the Declaration of Helsinki. Written consent was obtained from both the athletes and their legal guardians before enrolment. In line with national regulations, formal institutional ethics committee approval was not required, as the intervention was non-invasive and conducted within routine training activities.

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