



EFFECTS OF INTERNAL AND EXTERNAL ATTENTIONAL FOCI ON MOTOR SKILL LEARNING: TESTING THE AUTOMATION HYPOTHESIS

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THIAGO A.C. OLIVEIRA *, RENATA A. DENARDI, GO TANI, UMBERTO C. CORRÊA

University of São Paulo, São Paulo, Brazil

ABSTRACT

Purpose. This study investigated if (1) the beneficial effects of an external focus of attention on learning a motor skill were influenced by an internal focus of attention provided at initial instruction (2) or by an internal focus of attention at the early stage of the acquisition phase and (3) their relation to the automation hypothesis. **Methods.** Three separate experiments were performed with 168 college students on the acquisition, transfer, and retention of a golf-putting task. **Results.** In conjunction, the results of the three experiments pointed to the positive effects of an internal attention of focus instructions followed by an external attentional focus on motor learning. **Conclusions.** These results support the development of an alternative hypothesis on the effects of attentional focus on motor skill acquisition.

Key words: instruction, attention, motor learning, golf, external focus, internal focus

Introduction

Attention is an intriguing aspect of human behavior. When performing activities of daily living, humans encounter numerous situations in which they need to choose how, where, and when to focus their attention in order to be efficient. Attention has been referred to as a basic mechanism that allows for the selection of information, and it is closely related to concepts such as concentration, consciousness, mental effort, direction, excitability, and ability [1].

For over a century, researchers have developed models and theories to explain the limited attentional capacity of individuals, how they simultaneously or sequentially deal with various stimuli, and how they direct attention to relevant sources of information [2–6]. In the last few years, investigation on the performance and learning of motor skills has focused on the internal (i.e., movement patterns) and external (i.e., environmental characteristics) aspects of a task [7]. The results of this body of research have highlighted the superiority of external focus of attention on the performance and learning of motor skills in comparison to those based on internal focus and control (no attentional focus) [5, 8–14].

The main explanatory hypothesis for this is that the adoption of an external rather than internal focus of attention promotes greater automaticity in movement control [7]. It also has been suggested that the early stages of learning are shortened by the use of external foci [5, 7, 8]. Furthermore, it has been recognized that motor skill learning is characterized by a process that occurs in phases. For instance, the classical model by

Fitts and Posner [15] describes motor learning as three phases: cognitive, associative, and autonomous. In the first phase, the learner seeks to understand the task goal, but his/her attentional mechanisms are overloaded causing errors and inconsistent performance. In the subsequent phase (associative), the learner becomes able to associate with the movement and environmental information necessary to achieve the goal of the skill. As a result, the amount of error is diminished. The attentional requirements also significantly decrease as a result of a decrease in the variability of performance. Finally, the skill becomes automatic or learned (autonomous phase), that is, performance occurs under little or no influence from attentional demand. In other words, in this phase, the learner acquires the capability to cope with other relevant aspects of the task as processing becomes automatic and the level of conscious control of the task is diminished [6].

Of considerable interest is that the results in a number of aforementioned studies on the benefits of external foci did not take into account the previous introduction of internal foci. Specifically, in some studies, participants received instructions about the proper technique for completing the task prior to the experimental phase [5, 9, 11, 12], or had the opportunity to become familiar with the technique in practice trials [5, 11–13], which can be characterized as a source of internal foci. For example, Wulf [9] conducted a study to determine the influence of internal and external foci of attention on the learning of a golf swing. Twenty-two inexperienced students performed a golf swing task by hitting a circular target located 15 meters away. Participants in the internal focus group received information about the technique of the movement (a swinging motion of the arms) while those in the external focus group received information about club movement (performing a pendulum-like motion

* Corresponding author.

with the club). However, before the beginning of the practice phase, the experimenter explained and demonstrated the basic technique of the golf swing. All participants were given the same instructions on grip, stance, and posture. The results showed better performance by the external than the internal attentional focus groups in the retention test.

Given that information about a skill's technique, and, therefore, its movement pattern, refer to internal focus [7], we hypothesized that the beneficial effects of an external focus of attention on learning a motor skill could be influenced by an internal focus of attention provided during initial instruction, or even by an internal focus of attention at the earlier stages of the acquisition phase. These hypotheses were investigated by two experiments by also using a golf swing task. In a third experiment, we sought to investigate the effects of internal and external foci of attention on motor skill learning with regard to the aforementioned automation hypothesis. That is, as Wulf [7] observed, the adoption of an external rather than an internal attentional focus promotes greater automaticity in movement control. Interestingly, within a relatively large number of studies carried out so far, only McNevin and Wulf [10] and Poolton, Maxwell, Masters, and Raab [16] tested the automation hypothesis. However, these studies were not without their limitations, since Poolton, Maxwell, Masters, and Raab [16] did not consider the control group, and McNevin and Wulf's [10] conclusions were not restricted to their results.

Experiment 1

This experiment investigated whether the effects of an external focus of attention would be influenced by information based on an internal focus of attention provided during initial instruction.

Material and methods

Sixty college students (34 females and 26 males; M age = 23.4 y, SD = 5.6 y) were randomly selected. None had any experience with the motor task (golf putting), which allowed us to study the learning process considering all of its phases. Nonetheless, it is important to clarify that the participants were chosen as previous studies on attentional focus also used college students and that this population was deemed capable of completing the task and experimental procedures. The participants provided their written informed consent and the experimental protocol was performed in compliance with the guidelines of the American Psychological Association and approved by experimenter's university ethics committee.

The design and procedure of the task was based on previous studies [9, 11, 16] and, additionally, on a previously completed pilot study. The motor task selected was the golf putt [9, 11], performed on a mini-golf putting

green 5 m long and 1.5 m wide located in a closed room, with a hole as the target (with a diameter of 10.8 cm) at the end of the green. This design was similar to the one used by Poolton, Maxwell, Masters, and Raab [16]. Additional equipment included two golf clubs (putters), 10 golf balls, and a laptop computer for data collection. The golf putting task was performed by each participant one at a time.

The participants were randomly distributed into two internal focus (IF) groups and two external focus (EF) groups. The groups received the following instruction during the acquisition phase, for the IF groups they were directed to keep their attention specifically on the movement of the trunk and try to keep a straight path with the torso, while the EF groups were asked to direct their attention specifically to the head of the club and try to keep a straight path with the torso.

All groups watched a video of an athlete performing three putting shots. Afterwards, one group from each type of focus received additional instructions based on internal focus of attention via video by being told how important it is to move the torso in a straight path. These subgroups were designated as IF-EF and IF-IF.

The experimental design involved three phases: acquisition, transfer, and retention. All groups performed ten blocks of ten trials in the acquisition phase. A five-minute interval between each block was provided. In this phase, the stroke was performed from a distance of 3 m from the target. The transfer test involved performing two blocks of ten trials, with no instruction provided, but at a larger distance to the target (3.5 m). The retention test was performed exactly the same as the transfer test but took place seven days after the acquisition phase. At the end of the experiment all participants completed a questionnaire about where they directed their attention in order to determine whether or not it was done in accordance with the request of the experimenter.

For data analysis, hitting the ball into the target (hole) was treated as the dependent variable. Hits were registered in Microsoft Excel and analyzed in blocks of ten trials based on performance accuracy (number of balls hit in the hole) and variability (coefficient of variation). Performance by each group in the acquisition phase was analyzed using one-way ANOVA. Learning was assessed using the first and last blocks of the acquisition, transfer, and retention phases by two-way ANOVA (groups \times blocks). Observed effects were further analyzed using Tukey's Honestly Significant Difference (HSD) post-hoc test. For all analyses, the level of significance was set at $p < 0.05$. Statistical analysis was performed with Statistica 9.0 software (Statsoft Inc., USA).

It was hypothesized that the group provided with internal focus of attention during initial instruction followed by an external focus of attention during the practice (acquisition) phase would achieve the best results in learning the skill.

Results

Concerning the performance accuracy in the acquisition phase, one-way ANOVA revealed main effects for groups IF $F(9, 126) = 4.38, p < 0.01, \eta^2 = 0.24$, IF-IF $F(9, 126) = 8.31, p < 0.01, \eta^2 = 0.37$ and IF-EF $F(9, 126) = 18.75, p < 0.01, \eta^2 = 0.57$. Post-hoc tests indicated that these groups significantly improved their performance in the acquisition phase. No differences were found for the EF groups.

For learning, two-way ANOVA (4×6) revealed an interaction between groups and blocks $F(15, 280) = 2.03, p < 0.01, \eta^2 = 0.10$. It was verified that only the IF-EF group performed better in the transfer and retention tests than at the beginning of the acquisition phase (Fig. 1).

With regards to performance variability in the acquisition phase, one-way ANOVA revealed main effects for EF $F(9, 126) = 2.10, p < 0.05, \eta^2 = 0.13$, IF-IF $F(9, 126) = 1.95, p < 0.05, \eta^2 = 0.12$, and IF-EF $F(9, 126) = 2.98, p < 0.01, \eta^2 = 0.17$. Post-hoc tests indicated that variability increased in the first sets of blocks during acquisition but then decreased in subsequent blocks. No differences were found for the IF group. Additionally, no differences were revealed for learning by two-way ANOVA (Fig. 1).

Discussion

Several studies have indicated that learning with external foci is more effective than learning with an internal focus of attention [5, 8–14]. However, we understand that these studies had introduced internal foci prior to using external foci as their participants received

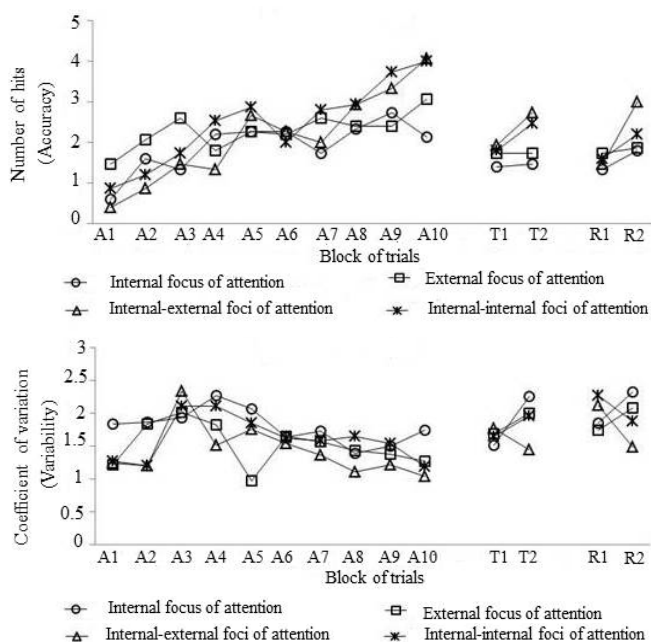


Figure 1. Mean number and coefficient of variation of hits in blocks of ten trials during the acquisition (A), transfer (T), and retention (R) tests of the four groups (IF, EF, IF-EF, IF-IF) in Experiment 1

information about the technique of the specific skill to be learned during initial instruction. Based on these aspects, we asked whether the prior introduction of an internal focus of attention would be something essential for learning, or rather, a pre-requisite for the effects of an external focus of attention to be effect on the learning of a motor skill.

Interestingly, the results of this experiment support this hypothesis. That is, the group with an internal focus of attention in instruction, followed by an external focus in the acquisition phase, was the only group that exhibited the best learning of the skill. A possible explanation for this result is related to the earlier stages of the learning process, but one that is not in accordance with Wulf's hypothesis [7], where an external focus leads to an acceleration of the learning process. Instead, it is believed that the internal focus may have contributed to the learning of skills in the earlier stages of learning. Thus, when the external focus of attention was introduced, the internal focus had already made it possible for the learners to understand what was to be done [15] or possibly even acquired the knowledge of the required movement [17].

Experiment 2

This experiment investigated whether or not the efficacy of an external focus of attention is dependent on prior practice with an internal focus of attention.

Material and methods

Sixty college students (21 females and 39 males; M age = 19.8 y, $SD = 7.7$ y), with no experience with the selected task were selected. Other aspects of the method (task, material, procedures, and data analysis) were similar to that in Experiment 1.

No specific instruction was given before the beginning of the experimental phase. The participants were distributed into four groups: those with an internal focus (IF) and external focus (EF) of attention during the acquisition phase, those provided with an internal focus in the first fifty trials followed by an external focus in the last fifty trials (IF-EF), and a group provided with an external focus of attention in the first fifty trials followed by internal focus in the last fifty trials (EF-IF). This was followed by transfer and retention tests similar to those in Experiment 1.

The hypothesis set forward in this experiment was that the group experiencing an internal focus before an external focus of attention during practice would achieve better results in terms of learning the skill than those without the prior internal focus of attention.

Results

In the acquisition phase, significant differences were revealed by ANOVA for all groups: groups IF $F(9, 126)$

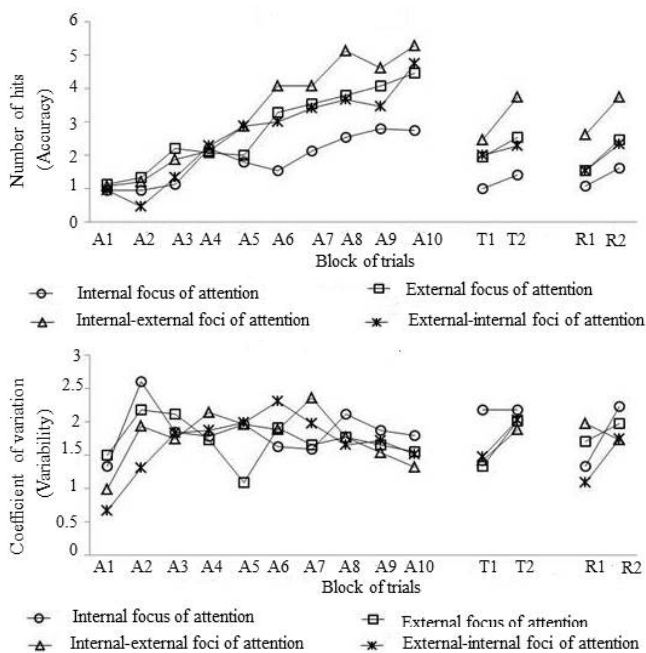


Figure 2. Mean number and coefficient of variation of hits in blocks of ten trials during the acquisition (A), transfer (T), and retention (R) tests of the four groups (IF, EF, IF-EF, IF-IF) in Experiment 2

= 4.78, $p < 0.01$, $\eta^2 = 0.25$; EF $F(9, 126) = 12.10$, $p < 0.01$, $\eta^2 = 0.46$; IF-EF $F(9, 126) = 23.13$, $p < 0.01$, $\eta^2 = 0.62$; and EF-IF $F(9, 126) = 27.25$, $p < 0.01$, $\eta^2 = 0.58$. Post-hoc analysis found that all groups improved their performance in the acquisition phase.

Similar to Experiment 1, the results of two-way ANOVA for learning revealed an interaction between groups and blocks trials $F(15, 280) = 1.77$, $p < 0.05$, $\eta^2 = 0.09$. Tukey's HSD test revealed that the IF, EF, and EF-IF groups improved their performance during the acquisition phase, but in the transfer and retention tests their rate of performance decreased to the original baseline. Group IF-EF was the only one that maintained their performance level in the transfer and retention tests (Fig. 2).

Regarding variability, in the acquisition phase significant differences were revealed by ANOVA only for groups IF-EF and EF-IF at $F(9, 126) = 2.44$, $p < 0.05$, $\eta^2 = 0.15$ and $F(9, 126) = 3.80$, $p < 0.01$, $\eta^2 = 0.21$, respectively. For both groups the post-hoc results showed that variability increased from the beginning to the middle of the acquisition phase and then afterwards decreased.

In relation to learning the skill, two-way ANOVA revealed effects only for blocks of trials $F(3, 280) = 5.19$, $p < 0.01$, $\eta^2 = 0.09$. Tukey's HSD test revealed that variability among the groups increased between the first acquisition block and the transfer and retention tests (Fig. 2).

Discussion

This experiment aimed at investigating whether practice under IF-EF would promote better learning when compared to other the forms of attentional focus. The

results allow one to reinterpret previous findings on the benefits of EF on motor skill learning. It seems that the efficacy of task performance increased in some studies [5, 7, 12] due to the participants being provided with an opportunity to become familiar with the task via the introduction of a prior internal focus of attention before practicing it with an external focus of attention.

Based on the results, it can be assumed that what promoted learning in the golf putter task was practice with an internal focus prior to practicing with an external focus of attention. The rationalization of these results is similar to that in Experiment 1, i.e., the internal focus of attention augmented performance in the earlier stages of learning by contributing to the understanding of the goal of the task [15] and/or the idea of the movement [17]. Thus, when an external focus of attention was introduced in the second half of practice, the learners could associate it with information on the movement pattern necessary in order to achieve the goal of the task.

Experiment 3

The final experiment focused on Wulf's hypothesis by investigating the effects of internal and external attentional foci on motor skill automation.

Material and methods

This group was comprised of 48 college students (23 females and 25 males; M age = 25.7 y, $SD = 5.8$ y). None of the participants had any experience with putting. The task, material, and procedures were similar to those in Experiment 1. The experiment involved two experimental phases: acquisition and retention. All participants practiced the golf putting task during the acquisition phase in ten blocks of ten trials each. The retention test was conducted 48 hours after the acquisition phase and involved completing ten trials.

The participants were divided into two groups of internal focus (IF) and two groups of external focus (EF) of attention. At the end of the acquisition phase, during the last block of trials, an additional task (distraction) was introduced to all groups, where the participants were asked to say the name of a loved one out loud simultaneously when executing the golf putt. After the acquisition phase, one group of each type of focus performed the retention test with the distraction task while the others did not.

Statistical analysis of the acquisition phase was similar to that in the previous experiments, employing 4×4 ANOVA (groups \times blocks) followed by Tukey's HSD test.

It was assumed that if an external focus of attention would facilitate automation during skill acquisition, the distraction task would not degrade the performance of the EF groups in any of the conditions.

Results

With regard to performance in the acquisition phase, one-way ANOVA revealed effects for all groups: IF with the distraction task during the retention test, $F(9, 99) = 8.55, p < 0.01, \eta^2 = 0.44$; IF without the distraction task during the retention test $F(9, 99) = 4.55, p < 0.01, \eta^2 = 0.29$; EF with the distraction task during the retention test $F(9, 99) = 8.55, p < 0.01, \eta^2 = 0.40$; and EF without the distraction task during the retention test $F(9, 99) = 4.96, p < 0.01, \eta^2 = 0.31$. Post-hoc analysis indicated that the groups improved in terms of performance in the acquisition phase until the ninth block, where their performance worsened from the ninth to the tenth block (Fig. 3).

With regards to learning, two-way ANOVA revealed significant differences only for blocks $F(3, 132) = 36.04, p < 0.01, \eta^2 = 0.45$. Tukey's HSD indicated that performance improved from the first to the ninth acquisition block ($p < 0.01$). For the subsequent blocks (tenth and the retention test), performance diminished ($p < 0.01$).

With regard to the variability of performance in the acquisition phase, one-way ANOVA revealed effects for only two groups: IF with the distraction task during the retention test $F(9, 99) = 2.29, p < 0.05, \eta^2 = 0.17$ and for EF without the distraction task during the retention test $F(9, 99) = 2.38, p < 0.05, \eta^2 = 0.17$. Post-hoc analysis indicated that variability among the groups increased in the acquisition phase until the ninth block. Two-way ANOVA on learning did not reveal any significant differences (Fig. 3).

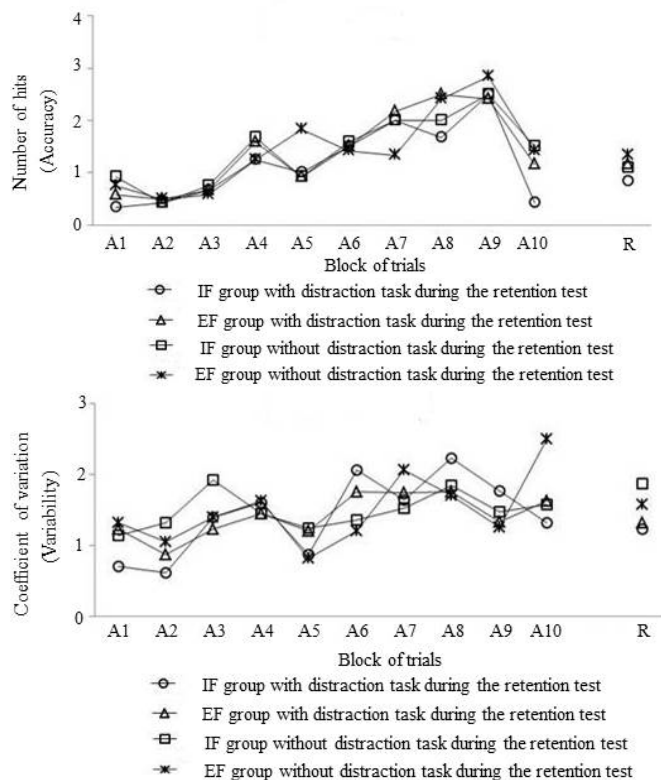


Figure 3. Mean and coefficient of variation of hits in blocks of ten trials during the acquisition (A) and retention (R) tests of the four groups in Experiment 3

Discussion

The aim of this experiment was to test the hypothesis that learning with an external focus of attention could lead to automation of a skill [7]. It was expected that the introduction of the distraction task would not disturb those groups with an external focus of attention, or if it did, it would distract them less than for the IF groups. This was considered to be likely due to the characteristics of automation: learners can direct attention to aspects other than those of task execution [6]. Additionally, as was suggested by Poolton, Maxwell, Masters, and Raab [16], the adoption of an external focus of attention might promote lower overload of working memory.

However, the results found a lack of differences between the groups at the end of the acquisition phase and that the introduction of the distraction task had the learners performing at a level similar to the one during the earlier phase. Interestingly, this was maintained even in the retention test.

A decrease in performance with the introduction of a new task is expected in a non-redundant system. According to the *theory of central resource capacity* [18], when two activities compete between themselves for attentional resources, the system can suffer. As a consequence, one of the “conditions” (performing the golf putting stroke or saying the name of a loved one out loud) might not be met with the required amount of attention and the activity cannot therefore be successfully completed [18]. As the results of the present experiment indicated, performance returned to the initial level at the tenth block of trials. Thus, it could be hypothesized that the learners did not reach a state of automation, as that would have allowed them to handle having their attention divided. The results of this experiment do not support the current literature on the subject [5, 7, 8, 10] in the sense that external focus did not promote skill automation among the participants.

Conclusions

In the acquisition of motor skills, individuals must manage receiving numerous types of information in order to perform a task successfully. For instance, in order to perform the putting stroke, a golfer has to cope with information such as body movement, proper hand grip on the club, the ball’s trajectory, the force used for the shot, and maintain focus on the target. This makes a somewhat simple motor skill seem relatively difficult [19]. The question then stands, how can it be possible to organize a practice procedure that could promote an efficient learning process?

An answer to this question has emerged from experimental research on attentional focus, including studies on the effects of internal and external focus on attention on motor skill acquisition [7]. These studies’ results have suggested that an external focus has a better effect on motor learning than internal focus of attention. The

main reasoning behind this is that external attentional focus facilitates automation of movement control and can shorten the initial stages of learning in such a way that a learner can achieve automation stage more quickly [7–8].

However, it seems that these findings have not taken one important fact into consideration: in much of the literature, learners received instructions with an internal focus of attention before that of an external focus [e.g. 5, 9, 11–13]. This was the main concern of the present study. We questioned whether the positive effects of an external focus of attention on motor learning could be influenced by the previously introduced internal focus of attention.

The results of this study support our hypothesis. In Experiment 1, it was observed that motor learning occurred only in the group that received information related to an internal focus of attention when initially being provided with instruction and then an external focus of attention during the acquisition phase. Similar results were observed in Experiment 2, in which an internal focus preceded an external focus of attention in the acquisition phase. Additionally, in Experiment 3, the results indicated that the realization of the automation stage was not facilitated by an external focus of attention.

These results refute the findings and hypotheses from the literature on attentional focus [7] and provide support to the proposition that motor skill learning occurs through an internal focus of attention in the initial instruction or acquisition phase, and then followed by an external focus of attention. As previously described, an alternative hypothesis for this proposition is that internal focus provides learners with comprehension of the task goal and/or that they are able to understand the idea of the movement (i.e., what is practiced in the first stage of the learning process) [15–17]. As a result, learners are better able to handle information from an external focus of attention as they can associate this information with that of the movement pattern, which is necessary for the successful performance of the task.

The results of the present study point to the positive effects of an internal focus of attention, followed by an external attentional focus, on motor learning. It is believed that these results can “open the door” for the development of an alternative hypothesis on the effects of attentional focus on motor skill acquisition. However, caution is advised when interpreting the results presented here, as although they were based on inferential statistics at a p value of 0.05, complementary descriptive statistics showed small effect size. Thus, performing additional studies similar to the one presented here is needed in order to confirm the results’ reproducibly.

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Correspondence address

Thiago Augusto Costa de Oliveira
School of Physical Education and Sport
University of São Paulo
Av. Mello Moraes, 65, Cidade Universitária
CEP 05508-030
São Paulo, SP, Brazil
e-mail: taco@usp.br