Universidade de Lisboa
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Effects of Motor Observation Supplementation on Quadriceps Muscle Activity and Torque Production during Isokinetic Resistance Exercise

Dissertação elaborada com vista à obtenção do Grau de Mestre em Treino de Alto Rendimento

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Abstract

Many studies have analysed the influence of verbal instructions and attentional focus on the performance of various motor tasks. Moreover, research has also shown that humans display a wide network of mirror-neurons and that motor observation can promote increased motor-system excitability. The purpose of this study was to explore the combined effects of motor observation and internally focused verbal instructions on skeletal muscle activity, torque production and other related variables during an isokinetic resistance-exercise protocol. We hypothesized that the addition of motor observation to internally focused verbal instructions might enhance neural input to the knee-extensor muscles, ultimately leading to greater muscle activity and greater torque production during resistance exercise when compared to verbal instructions alone. We conducted a crossover design using two conditions: a control condition in which the participants received internally focused verbal instructions and an experimental condition including the same instructions, but supplemented with motor observation of the same exercise. Both groups performed 6 sets of 10 repetitions on an isokinetic dynamometer. Leg extension torque and EMG activity of the vastus mediallis, rectus femoris, vastus lateralis and bicep femoris was obtained. Results showed no statistically significant main effects for condition in peak torque ($F = 0.343$; p value = 0.573; $\eta^2 = 0.037$) nor surface electromyographic activity of the analysed muscles: vastus mediallis ($F = 0.002$; p value = 0.966; $\eta^2 = <0.001$), rectus femoris ($F = 0.138$; p-value = 0.718; $\eta^2 = 0.015$), vastus lateralis ($F = 0.031$; p value = 0.863; $\eta^2 = 0.003$) or biceps femoris ($F = 0.544$; p value = 0.476; $\eta^2 = 0.058$). These results suggest that motor observation has no additional effect on torque production or muscle activity when compared to that seen with internally focused verbal instructions alone.

Keywords: Attentional Focus; Verbal Instruction; EMG; Mirror-Neurons; Isokinetic Training.

Resumo

Vários estudos têm analisado os efeitos da instrução verbal e de diferentes tipos de foco atencional ao nível do desempenho de diferentes tarefas motoras. Além disso, a literatura disponível também evidencia que os humanos possuem uma rede complexa de neurónios espelho e que a observação motora pode promover um aumento da excitabilidade cortical. O objetivo deste estudo foi analisar os efeitos combinados de observação motora e instrução verbal com foco atencional interno na ativação eletromiográfica do músculo esquelético, produção de torque e outras variáveis associadas na resposta a uma sessão de treino de força em regime isocinético. Estabeleceu-se a hipótese de que a suplementação da instrução verbal interna com a observação motora poderia aumentar o *drive* neural sobre os músculos extensores do joelho e assim potenciar uma maior atividade eletromiográfica e produção de torque quando comparada com utilização exclusiva da instrução verbal. Para testar esta hipótese recorreu-se a um desenho experimental cruzado com duas condições: uma condição de controlo que implicou instruções verbais com foco atencional interno e uma condição experimental que envolveu o mesmo tipo de instruções, mas ao qual foi adicionada a observação motora da tarefa a ser realizada durante a execução da mesma. Ambos os grupos realizaram 6 séries de 10 repetições num dinamómetro isocinético. Foram analisados o torque de extensão do joelho e EMG dos músculos vasto medial, reto femoral, vasto lateral e bicípite femoral. Não foram observados efeitos significativos para efeitos entre condições referentes aos valores de torque máximo (F = 0.343; p value = 0.573; η^2 = 0.037), ou de atividade eletromiográfica dos músculos analisados: vasto medial (F = 0.002; p value = 0.966; η^2 = <0.001), reto femoral (F = 0.138; p value = 0.718; η^2 = 0.015), vasto lateral (F = 0.031; p value = 0.863; η^2=0.003) ou bicípite femoral (F = 0.544; p value = 0.476; η^2 =0.058). Os resultados obtidos sugerem que a observação motora não promove qualquer efeito adicional sobre a produção máxima de torque ou de atividade eletromiográfica dos músculos envolvidos, quando comparada com utilização exclusiva de instruções verbais com foco atencional interno.

Palavras chave: Foco Atencional; Instrução Verbal; EMG; Neurónios-Espelho; Treino Isocinético

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List of Abbreviations

AAR- Antagonist/Agonist Ratio

ACSM- American College of Sports Medicine

ARS- Average Rectified Signal

BF- Bicep Femoris

EMG- Electromyography

MO- Motor Observation

NME- Neuromuscular Efficiency

RF- Rectus Femoris

SENIAM- Surface Electromyography for the Non-Invasive Assessment of Muscles

sEMG- Surface Electromyography

VL- Vastus Lateralis

VM- Vastus Medialis

1.Review of the Literature

1.1.Introduction to Attentional Focus and Verbal Instructions

Verbal instructions can be used to direct the performer's focus of attention (i.e. the selective attention during a specific motor task) either internally, focusing on bodily movements and sensations, or externally whereby an individual shifts his focus to the outcome of a given motor task. In recent years many studies have analysed the influence of verbal instructions on the performance of various motor tasks (1). A vast body of research has shown that the direction of the performer's focus of attention (e.g. internal vs. external) can have significant effects on movement kinetics, efficiency, muscular activity, and force production (1,2). Specifically, the adoption of an external focus of attention results in better motor control and movement efficiency in a wide range of performance-oriented motor tasks (1). In contrast, an internal focus of attention increases surface electromyography (sEMG) compared to an external focus (3–5), even while producing equal or lower force outputs (2,3).

Interestingly, even though it has recently been shown that the adoption of an internal focus of attention during resistance training exercise results in increased muscle activity (2,3,5–9), the concept of a "mind-muscle connection" is not new to the bodybuilding community (10). This concept advocates that the exercising individual should visualize and direct his focus to the target muscle in an attempt to enhance the neural drive to a specific muscle or muscle group, thereby increasing its activation, while minimizing the activity of antagonist muscles during a given motor task (10). Although these studies suggest a benefit of using verbal instruction to increase sEMG amplitude, whether increased sEMG amplitude can lead to superior long term muscle adaptations remains highly controversial (11,12). Indeed, muscle adaptations, such as exercise induced hypertrophy are mediated by several signalling pathways which can be influenced by different factors, such as mechanical tension, metabolic stress, and muscle damage, which are fine-tuned by the manipulation and interplay of various resistance training variables (13). This makes it unlikely that one single acute measure of muscle activation may accurately predict long-term muscle adaptations. For instance, past research has shown that muscle hypertrophy can be achieved through the use of a wide range of loading zones if sets are carried to momentary muscular failure (14,15). This is relevant because heavier-load training (80% of one-repetition maximum - 1RM) is known to promote greater acute sEMG amplitudes compared to that seen with lighter loads (30% 1RM), even when sets are carried to momentary muscular failure (16,17).

To further illustrate the labile relationship between acute sEMG amplitude and chronic muscle hypertrophy, it has been recently shown that increased cross-sectional area and muscle thickness can occur secondary to long lasting passive stretching in humans (18,19). This effect is similar to that already described in other animals (20,21), suggesting that factors other than muscle activation explain a great proportion of variance in muscle hypertrophy. In addition, within subject, as well as within muscle factors, can exert a powerful influence on sEMG amplitude, thus contributing for this lack of relationship between acute and chronic effects (e.g. fatigue, electrode position/movement and tissue conductivity - factors that are challenging to control during dynamic contractions) (11). Therefore, caution is advised when attempting to extrapolate results from acute measures to make predictions related with chronic muscle adaptations. Ultimately, it can be concluded that further longitudinal studies should be conducted before drawing conclusions on the effectiveness of different training protocols or attentional focus strategies based solely on sEMG data.

1.2.Long Term Effects of Different Attentional Focus Strategies

In this regard, Schoenfeld et al. recently reported that the use of verbal instruction with an internal focus of attention results in a greater magnitude of increase in muscle thickness of the elbow flexors after 8 weeks of resistance training, although no significant effect was noticed for the quadriceps muscle (22). This finding suggests that the use of verbal instructions, emphasizing an internal focus of attention, can indeed enhance resistance training adaptations such as muscle hypertrophy and that this attentional focus strategy effects likely depends on the muscle being exercised. In a recent meta-analysis exploring the acute and long-term effects of different attentional focus strategies on muscular strength, it was shown that the use of an external focus of attention elicits an acute increase in force production (23). Yet, no significant long-term effects were detected, although a subgroup analysis (considering only gains in lower-body strength) did find a positive effect of training with an external focus on strength gains (23). Similar results were also reported for muscular endurance, in which the use of an external focus of attention was associated with greater muscular endurance (24).

Taken together these studies suggest that different attentional focus strategies can have a different influence on muscle adaptations. In specific, while an external focus might be well suited for strength gains and muscular endurance, an internal focus might be preferable when the desired outcome is muscle hypertrophy (at least at the level of the upper body). In addition, these data reinforce the importance of standardizing verbal instructions and cues during muscular strength and endurance tests, as this can have a direct influence on the observed results (23).

1.3.Mirror-Neuron System

There is evidence that, as is it is also seen in lower primates, humans have a specialized mirror-neuron system - a peculiar group of neurons that has the particularity of firing when a motor task is performed and when a similar motor action is observed (25,26). Mirror neurons were first discovered in the premotor cortex of the monkey's brain (26). This special group of neurons fires both when the animal does a particular action, as well as when it observes another individual performing the same action (26). The available research suggests that the mirror-neuron system is involved in a broad range of cognitive functions, such as action understanding, imitation and social cognition (26,27)..

Since these neurons were first discovered in the monkey's brain, much research has been conducted on investigating the existence of brain regions with mirror properties in humans (25,27,27,28). Early studies suggested that, in humans, the mirror-neuron system is formed by a complex network involving occipital, temporal, parietal, as well as other cortical regions that have predominantly motor functions (26). Recent evidence from human brain functional magnetic resonance imaging (fMRI) corroborated these results, showing a wide network of brain regions with mirror properties (i.e. regions activated with the action of observation and execution), including the inferior frontal gyrus, dorsal and ventral premotor cortex and the inferior and superior parietal lobule (27). In line with this, several studies have reported an increased motor-system excitability, characterized by a facilitation of motor-evoked potentials (MEP's), in circumstances involving the observation of a motor task being performed by another subject (25,29). Furthermore, these studies suggest that the pattern of muscle activation evoked is very similar to the pattern of muscle contraction obtained during the execution of the same action, suggesting that motor observation may enhance cortical motor excitability in a pattern specific to that seen during task execution (25,29).

Contrasting with the concept of a cortical-related mirror effect, another study suggested that the spinal cord might be modulated in an antagonistic way to that expected during motor action execution (30). In this study, the authors analysed the H-reflex excitability during a finger-flexing task while the participants observed a specific hand action (hand reaching and grasping of a sphere). The authors found a significant modulation of the H-wave amplitude related to the different phases of the observed movement. Curiously, instead of showing a pattern similar to that expected during action execution, they found that the H-reflex exhibited an opposite pattern (increased during finger extension and decreased during finger flexion). Ultimately, this suggests that spinal motoneurons of the finger flexors were facilitated during observation of the hand opening (i.e.: finger extension) and inhibited when participants observed the hand closing (i.e.: finger flexion), a pattern which seems opposite to that expected when muscles are actually executing the hand opening and hand closing actions.

Based on these data, it can be said that, although cortical excitability mimics the observed movements as if they were performed in the first person, the spinal cord appears to be modulated in an opposite direction to that expected during action execution (i.e. inhibition), likely preventing the involuntary replication of the observed motor actions. Despite this, whether this spinal “inhibition“ persists in circumstances in which the observer intends to replicate the observed action, remains largely unknown. As importantly, it has not yet been determined if an increased cortical excitability can lead to heightened muscle activity at the level of the agonist muscle groups during the execution of a motor task, paired by synchronous visual observation. If this was the case, it might be possible to combine motor observation with the execution of the observed motor task to increase the neural output to the agonist muscles through increased cortical excitability. At last, this might have important implications in the field of strength and conditioning.

Finally, the revelation of the intricate relationships between motor observation and motor execution, through the mirror-neuron system, led to the development of motor-task observation therapy in rehabilitation settings (31). This therapeutic approach implies the systematic observation of movements to facilitate the engagement of the motor system and is mainly used in the field of neurological rehabilitation (31). The existent data has shown promising results on the field of neuromotor rehabilitation in patients with Parkinson’s disease and ischemic encephalopathy (31,32). Unfortunately, its use in musculoskeletal rehabilitation has been less investigated.

2.Aims

Considering all these factors, this study aims to study the effects of verbal instruction, with and without motor observation, on sEMG activity and isokinetic torque production during isokinetic leg-extension exercise. It is hypothesized that the supplementation of motor observation to internally focused verbal instructions might enhance the neural drive to the exercising muscles, ultimately leading to greater muscle activity and possibly greater torque production during resistance exercise when compared to the use of verbal instructions alone.

3.Methods

3.1.Ethical Approval

All participants provided written informed consent prior to their inclusion. This study complied with the principles set forth in the Declaration of Helsinki and was approved by the Faculty's Ethics Committee (CEFMH nº: 6/2022).

3.2.Participants

Ten young male and healthy participants (Table 1) were recruited from local communities via word of mouth. Physical activity levels were assessed using a translated version of "The Aerobics Centre Longitudinal Physical Activity Questionnaire" (33) (Annex 2.) and they all completed a health screening questionnaire (Annex 1.). The inclusionary criteria were as follows: (1) no existing musculoskeletal disorders, (2) no consumption of anabolic steroids or any performance-enhancing drugs, (3) training experience defined as participating in at least 2 sessions per week of lower-body resistance training during the past year, and (4) relative leg-muscle strength > 70th percentile of ACSM's Guidelines for Exercise Testing and Prescription (34). Exclusionary criteria included active smoking status, known metabolic disease, cardiovascular disease, respiratory disorders including asthma and any orthopaedic issues that would limit exercise performance. Leg dominance was assessed using the Waterloo limb-dominance questionnaire (35) (Annex 3.).

Table 1. Participants' characteristics (n=10)

Age (years)	23.9 ± 1.6
Height (m)	1.72 ± 0.20
Body Mass (kg)	77.8 ± 12.1
Years of Experience	4.2 ± 2.6

Values are reported as Mean ± SD

3.3.Study Design

A crossover study design was used to examine the acute effects of combining motor observation and internally focused verbal instructions on kinetic and neuromuscular performance in response to six sets of maximal isokinetic concentric leg extension at 90º.s^{-}. Two conditions were set: (1) a control condition, in which the participants were given an internally focused verbal instruction to focus on squeezing the quadriceps muscle (VERBAL); (2) a motor observation condition (MO), requiring the participants to observe a computer screen displaying a video of a leg-extension exercise, using a first-person perspective (while still receiving the internally focussed verbal instruction). The sequence of allocation to each condition was randomized based on a computer-generated algorithm.

3.4.Verbal Instruction

In both conditions the participants were given internally focused verbal instructions as those used in previous studies exploring the effects of an internal focus of attention and the mind-muscle connection during resistance training (5,22,36). Instructions consisted in the following: “During this set try to focus on squeezing your quadriceps muscle”, “Contract your quadriceps”, “Squeeze the muscle” “focus on squeezing the muscle”, Focus on squeezing your leg muscles”, “Feel the contraction”. Instructions were given before and during the execution of each set. All participants were students of sports sciences or related courses, were familiarized with human anatomy and therefore knew the anatomy of the leg muscles.

3.5. Motor Observation

In the motor observation condition the participants were required to observe a computer screen displaying a video of a leg-extension exercise, using a first-person perspective (while still receiving the internally focussed verbal instruction). The video consisted in the completion of a set at the same angular velocity as prescribed during the experimental conditions. During each set, the participants were also given the same internally focused verbal instructions as the control group and were continually reinforced to look at the computer screen.

3.6. Familiarization and Testing

To be included in the study, the participants were screened for their maximal concentric strength on a horizontal leg press machine according to the American College of Sports Medicine guidelines (34). Before the screening session began, all participant were required to fill the required questionnaires. After this the session then began with a 3 min warm-up using callisthenic exercises. After this, 10 repetitions were performed on the leg press machine at a relatively comfortable intensity. Then, each participant was requested to select a load that he would be able to perform for 3-5 reps. From then on, single trials were performed with 10 to 20% load increases until the strength criteria were met (2.2 x body mass in kg). A maximum of 4 trials were allowed with a 3-5 min rest period between trials, in accordance to American College of Sports Medicine guidelines (34). Testing was ended once participants met the relative strength ratio required for inclusion. Only those exhibiting a relative strength ratio > 70th percentile were included to prevent the inclusion of non-strength trained participants. Participants that met all the inclusion criteria then proceeded to familiarization.

For familiarization and testing, each participant visited the laboratory on three non-consecutive days (all between 9:00-16:00 hours) and was asked to refrain from engaging in lower-body exercise at least 48 hours before testing. The familiarization consisted of isokinetic unilateral leg extensions using the dominant limb performed on an isokinetic dynamometer (Biodex System 3 Pro; Biodex Medical Systems, NY, USA). Participants were seated with their hip positioned at 85º (supine position = 0°) and were strapped around their chest and hips to avoid any extraneous movement. The knee centre of rotation was aligned with the dynamometer axis of rotation, and the lever arm was firmly attached to the lower leg using proper inextensible straps placed 2 cm above the medial malleolus. Knee extension velocity was set at 90º/s. The familiarization consisted of a warm-up: two sets of ten light repetitions, two sets of five moderate intensity repetitions and finally three maximal repetitions with 60 s of rest between them. After that, three sets of ten maximal repetitions were performed with two-minute rest in between. All participants received strong verbal encouragement, including internal focus cues (in accordance to that previously described).

On the second day, after the same general warm-up, the participants were given a 5min rest before they were randomly assigned to exercise with either verbal instruction or motor-observation. On the third day participants performed the remaining exercise condition, using the same procedure as previously described. The resistance training protocol used was similar to one used in another study evaluating the effects of isokinetic leg extension training on quadricep sEMG (37).This protocol was used because it more accurately represented a typical training session consisting of multiple sets and was previously used to analyse the effects of isokinetic resistance training on peak torque and sEMG which were our main variables as well. Each session consisted in six sets of 10 maximal isokinetic concentric knee extensions at 90º/s with two-minute rest between sets.

3.7.Data Collection

All torque signals (including the isokinetic testing) were A/D converted (MP100 – Biopac™ Systems, 16-bits) with a sample rate of 1000 Hz and low pass-filtered (12 Hz, 4^{th} order Butterworth) using a custom-built routine for analysis(MATLAB version R2018a). During each test and exercise protocol, EMG data was acquired using bipolar surface electrodes (Bagnoli 8™, Delsys Inc., Massachusetts, USA). A total of 4 electrodes were placed in the following muscles: Vastus Medialis (VM), Vastus Lateralis (VL), Rectus Femoris (RF) and Bicep Femoris (BF) according to the previously mentioned SENIAM recommendations (38). Before the electrode placement, the skin was shaved and cleaned first with alcohol and secondly with Nuprep® (Weaver and Company, Colorado, USA) skin prep gel to minimize impedance. EMG signals were pre-amplified and band pass-filtered between 20 and 450 Hz, while digitalized at 1000 samples/s. After this the signal was rectified and smoothed with a low-pass filter (12 Hz, 4^{th} order Butterworth).

3.8.Data Processing

Peak torque was defined as the highest value of torque measured in each repetition. Average peak torque values were then calculated for each set. Work output was calculated as the integral of torque-angular displacement curve (39). Data was normalized to the mean value of the 100 ms time window across the EMG peak. Average rectified values of all muscles were calculated at each repetition during the isokinetic protocol between 120º and 150º of knee extension (330 ms) (40).

A modified isokinetic fatigue index, based on previous work by Gomes (Gomes et al., 2021), was computed to explore the effects of fatigue as a percentage decrease of peak torque and work output. This index was calculated using peak torque and work output data as following:

$$Fatigue\ Index = \frac{(\mu\ \text{3 highest consecutive repetitions} - \mu\ \text{last 3 repetitions})}{(\mu\ \text{3 highest repetitions})} \times 100$$

Neuromuscular efficiency was calculated as the ratio between normalized sEMG activity and peak torque for each repetition. The antagonist-agonist ratio was computed as the ratio between BF and VL normalized sEMG activity.

3.9.Statistical Analysis

Based on a previous study (3) which compared the effects of verbal instruction on muscle integral EMG, an effect size of F = 0.52 was calculated using the statistical software G*Power version 3.1.9.6 (41). To obtain a statistical power of at least 0.8, a sample size of 8 participants would be required. Data obtained was tested for normality and sphericity with the Shapiro-Wilk and Mauchly’s tests, respectively. We conducted two-way repeated measures ANOVA’s using a within-subject design with condition-by-set factors to analyse differences between conditions for each variable. Additionally two-way repeated measures ANOVA´s using a within-subject design with condition-by-muscle factors were computed for each set to analyse any possible differences in muscle activity between conditions. The Greenhouse-Geisser corrections were used to analyse main effects, whenever sphericity could not be assumed. Pairwise comparisons were made using Bonferroni’s corrections. Partial η^2 was calculated as a measure of effect size for main effects. Data analyses were performed using SPSS software version 27.0 (SPSS Inc., Chicago, IL, USA) and statistical significance was set at $p < 0.05$.Post-hoc tests with Bonferroni corrections were used to analyse significant main effects.

4.Results

4.1.Peak torque

The 2-way repeated measures ANOVA for peak torque provided no significant main effect of condition (F= 0.343; p value= 0.573; η^2= 0.037) or condition-by-set (F = 0.857; pvalue= 0.430; η^2= 0.087), while revealing a significant main effect of set (F = 4.991; p value = 0.035; η^2= 0.357). Despite this, post-hoc comparisons for set main effects revealed no significant difference between any of the sets. Peak torque values for each condition across sets are shown in figure1.

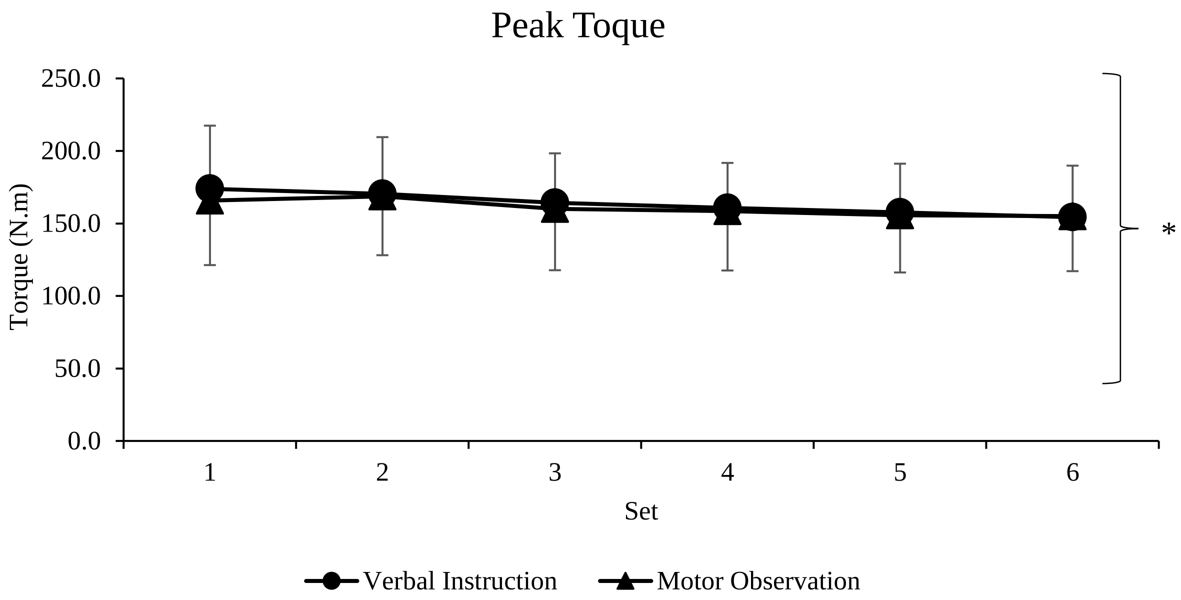

Fig.1: Average Peak torque (N.m) for each set for each condition. A significant main effect was found for set. Markers represent the Average of Peak Torque values for each set. Error Bars pointing up represent Verbal Instruction Std. Deviation while Error Bars pointing down represent Motor Observation Std. Deviation. Circles represent Verbal Instruction and Triangles the Motor Observation Conditions respectively. *Represents a main effect of set (explained in the text).

4.2.Work Output

For work output, only a significant main effect of set was found (F = 4.654; p value = 0.034; η^2 = 0.341). Yet, post-hoc comparisons resulted in no significant differences between sets. No significant main effects were found for condition (F = 0.028; p value = 0.872; η^2 = 0.003) or condition-by-set interaction (F = 1.241; p value = 0.309; η^2 = 0.121). Work output values for each condition across sets are shown in figure 2.

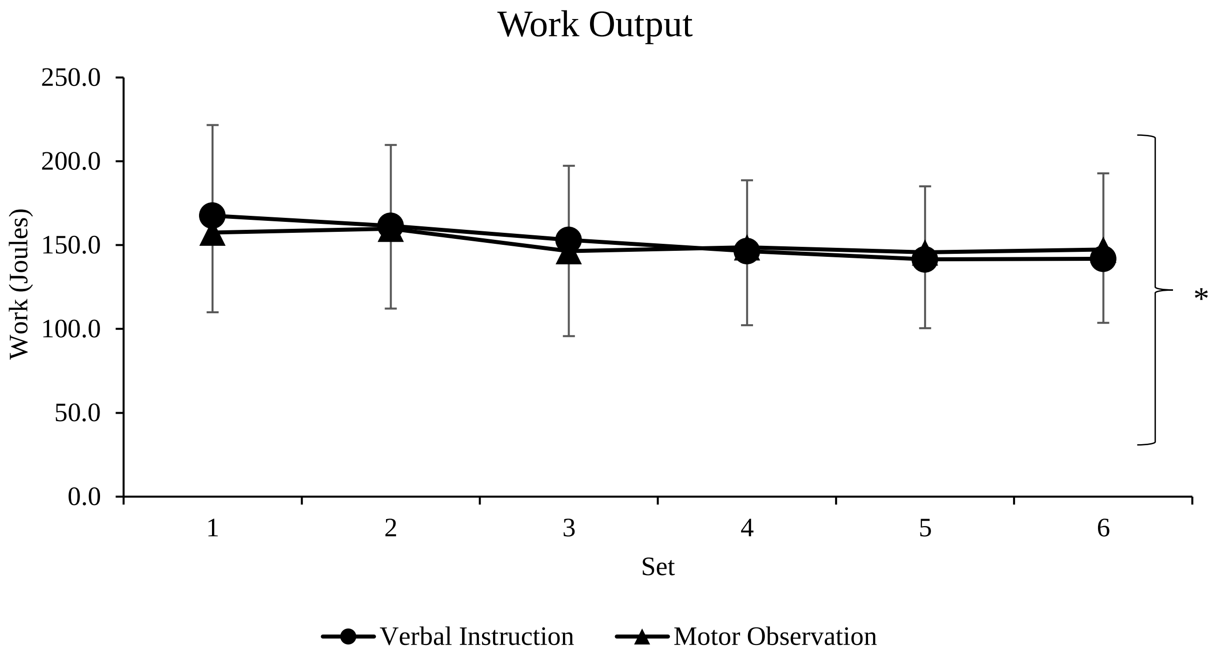

Fig.2: Average Work Output (Joules) for each set for each condition. A significant main effect was found for set. Markers represent Average Work Output Values for each set. Error Bars pointing up represent Verbal Instruction Std. Deviation while Error Bars pointing down represent Motor Observation Std, Deviation. Circles represent Verbal Instruction and Triangles the Motor Observation Conditions respectively. * * *Represents a main effect of set (explained in the text)

4.3.Peak Torque Fatigue Index

No significant main effect was obtained for condition (F =1.355; p value = 0.274; η^2 = 0.131), set (F = 3.277; p value = 0.055; η^2 = 0.267) or condition-by-set interaction (F = 0.797; p value = 0.558; η^2 = 0.081) for the peak torque fatigue index (Table.3).

4.4.Work Output Fatigue Index

Only a significant main effect was found for set (F = 8.991; p value < 0.001; η^2= 0.500). Post hoc comparisons indicated significant differences between set 1 vs. set 4 (mean difference of -7.797; p value = 0.021; St. Error = 1.715), set 1 vs set 5 (mean difference of -9.522; p value = 0.012; St Error = 1.937), set 1 vs set 6 (mean difference -11.787; p value = 0.007; St Error = 2.222) and set 2 vs set 6 (mean difference of -10.498; p value = 0.018; St

Error = 2.263). No significant main effect was obtained for condition (F = 0.146; p value = 0.711; η^2 = 0.016) or condition-by-set interaction (F = 0.527; p value = 0.755; η^2 = 0.055) for the work output fatigue index (Table.3).

4.5.*EMG Amplitude*

Two-way repeated measures ANOVA's resulted in no significant main effect of condition for EMG amplitude of the VM (F = 0.002; p value = 0.966; η^2 <0.001), RF (F = 0.138; p value = 0.718; η^2 = 0.015), VL (F = 0.031; p value = 0.863; η^2 = 0.003) or BF (F = 0.554; p value = 0.476; η^2 = 0.058). A significant main effect of set was found for the RF (F = 10.477; p value = 0.001; η^2 = 0.538). However, post-hoc comparisons resulted in no significant differences between individual sets. No main effect of set was detected for any other muscle: VM (F = 0.471; p value = 0.568; η^2 = 0.050), VL (F = 1.175; p value = 0.321; η^2 = 0.115), BF (F = 0.659; p value = 0.492; η^2 = 0.068).

A significant condition-by-set interaction was found for the BF (F = 2.809; p value = 0.027; η^2 = 0.238). After testing for post-hoc comparisons, no significant differences were detected between sets. No main effects of condition-by-set interactions were detected for any other muscles: VM (F = 0.341; p value = 0.638; η^2 = 0.037), RF (F = 0.529; p value = 0.634; η^2 = 0.056), VL (F = 0.410; p value = 0.602; η^2 = 0.044). Mean values and standard deviations can be seen in table 2.

Two-way repeated measures ANOVA´s using a condition-by-muscle approach on each set revealed a significant main effect for muscle in set 4 (F = 3.962; p value = 0.038; η^2 = 0.306), set 5 (F = 4.035; p value = 0.036; η^2 = 0.310) and set 6 (F = 4.983; p value = 0.019; η^2 = 0.356). Post-hoc comparisons indicated significant differences between the EMG amplitude of the VM and RF in set 4 (mean difference of 18.482; p value = 0.024; St.Error = 5.445), set 5 (mean difference of 18.245; p value = 0.028; St. Error = 5.527) and set 6 (mean difference = 24.275; p value = 0.014; St.Error = 6.536). No other significant main effects were found.

4.6.Neuromuscular Efficiency

No significant main effect was found for condition (F = 0.166; p value = 0.693; η^2 = 0.018), set (F = 0.193; p value = 0.713; η^2 = 0.021) or condition-by-set interaction (F = 0.336; p value = 0.662; η^2 = 0.036). All p values and η^2 for each variable can be seen in

Table 4. Mean values and standard deviations for peak torque and work output, peak torque and work output fatigue indexes, antagonist-agonist ratio and neuromuscular efficiency can be seen in Table 5, Table 6 and Table 7 respectively.

4.7. Antagonist-Agonist Ratio

No significant main effect was found for condition (F = 0.314; p value = 0.589; $\eta^2 = 0.034$), set (F = 0.924; p value = 0.403; $\eta^2 = 0.093$) or condition-by-set interaction (F = 0.597; p value = 0.529; $\eta^2 = 0.062$).

Table 2. EMG activity for each muscle across conditions for each set.

	Set	1		2		3		4		5		6	
Condition		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Verbal	VM	105.4	26.1	107.4	34.7	107.3	43.2	106.0	50.4	107.8	53.2	109.3	55.4
	RF	101.8	20.5	98.9	24.0	91.8	21.5	86.1	22.6	84.7	23.8	83.9	20.6
	VL	104.3	19.9	107.5	29.1	101.3	29.5	98.7	38.0	93.8	42.5	91.8	45.0
	BF	86.5	16.0	89.8	24.1	79.9	19.2	81.1	32.3	77.1	32.5	73.4	32.1
MO	VM	102.4	28.1	104.7	30.1	103.0	30.7	108.4	32.8	106.5	28.9	112.5	32.2
	RF	102.0	26.3	102.0	22.8	93.5	26.4	91.4	29.5	93.2	27.7	89.3	26.6
	VL	102.6	22.3	106.7	18.2	102.2	22.2	101.2	26.1	97.6	25.8	100.3	31.4
	BF	84.8	18.5	88.1	17.9	84.5	18.6	90.4	20.4	89.7	25.0	85.9	22.9

Values are reported as Mean ± SD. Values represent mean normalized amplitude (%).

Abreviations: MO: Motor Observation; VM: Vastus Medialis; RF: Rectus Femoris; VL: Vastus Lateralis; BF:Bicep Femoris

Table 3. P-values and η^2 of EMG main effects of the quadriceps muscles for each set

	Condition		**Muscle**		**Condition x Muscle**	
set nº	**P-value**	η^2	**P-value**	η^2	**P-value**	η^2
1	0.903	0.002	0.868	0.009	0.933	0.008
2	0.992	0.000	0.484	0.078	0.877	0.014
3	0.969	0.000	0.080	0.245	0.761	0.016
4	0.833	0.005	0.038*	0.306	0.973	0.003
5	0.812	0.007	0.036*	0.310	0.803	0.024
6	0.730	0.014	0.019*	0.356	0.947	0.006

Significant main effects for muscle were found. Post hoc comparisons revealed significant differences between VM and RF in sets 4, 5 and 6. *Represent statistical significance.

Table 4. P-values and ɳ² of main effects for all analysed variables

	Condition		Set		Condition x Set	
Variable	**P-value**	**ɳ²**	**P-value**	**ɳ²**	**P-value**	**ɳ²**
EMG VM	0.966	<0.001	0.568	0.050	0.638	0.037
EMG RF	0.718	0.015	0.001*	0.538	0.634	0.056
EMG VL	0.863	0.003	0.321	0.115	0.602	0.044
EMG BF	0.476	0.058	0.492	0.068	0.027*	0.238
Peak Torque	0.573	0.037	0.035*	0.357	0.430	0.087
Peak Torque-Fatigue Index	0.274	0.131	0.055	0.267	0.558	0.081
Work Output	0.872	0.003	0.034*	0.341	0.309	0.121
Work Output-Fatigue Index	0.711	0.016	<0.001*	0.500	0.755	0.055
AAR	0.589	0.034	0.403	0.093	0.529	0.062
NME	0.693	0.018	0.713	0.021	0.662	0.036

*Represent statistical significance. Values correspond to mean ± SD. Abbreviations: VM: Vastus Medialis; RF: Rectus Femoris; VL: Vastus Lateralis; BF: Bicep Femoris; AAR: Antagonist-Agonist Ratio; NME: Neuromuscular Efficiency

Table 5. Mean ± SD for average peak torque and average work output in each set

	Peak Torque (N.m)				Work (J)			
	Verbal		MO		Verbal		MO	
set nº	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
1	173.9	43.6	165.7	44.4	167.6	54.1	157.5	47.6
2	170.5	39.0	168.6	40.6	161.6	48.2	159.8	47.7
3	164.2	34.2	160.1	42.4	153.0	44.3	146.5	50.8
4	160.6	31.1	158.4	40.9	146.4	42.2	148.8	46.6
5	157.5	33.7	155.6	39.4	141.5	43.5	145.7	45.3
6	154.3	35.6	155.0	38.0	141.8	51.0	147.4	43.8

Values are reported as Mean ± SD. Abreviations: MO-Motor Observation; SD-Standard Deviation

Table 6. Mean ± SD for peak torque and work output fatigue indexes

	Peak Torque Fatigue Index				Work Output Fatigue Index			
	Verbal		MO		Verbal		MO	
set nº	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	13.2	4.6	12.8	8.4	12.2	8.1	12.8	10.9
2	13.5	2.1	12.5	8.2	16.5	5.8	10.9	8.9
3	16.6	7.3	17.5	7.3	17.9	8.7	18.5	11.6
4	17.3	3.6	17.0	6.2	19.3	6.4	21.2	8.4
5	20.3	6.6	16.5	8.1	22.4	9.2	21.5	10.0
6	20.4	12.0	17.2	10.4	24.5	9.5	24.0	11.6

Values are reported as Mean ± SD. Abbreviations: MO-Motor Observation; SD-Standard Deviation

Table 7. Mean ± SD for Antagonist-Agonist Ratio and Neuromuscular Efficiency

	Antagonist-Agonist Ratio				Neuromuscular Efficiency			
	Verbal		MO		Verbal		MO	
set nº	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.9	0.2	0.8	0.1	0.6	0.2	0.7	0.2
2	0.9	0.2	0.8	0.2	0.6	0.2	0.7	0.2
3	0.8	0.2	0.8	0.2	0.6	0.2	0.7	0.2
4	0.9	0.2	0.9	0.2	0.6	0.2	0.7	0.2
5	0.9	0.2	1.0	0.4	0.6	0.3	0.7	0.2
6	0.9	0.2	0.9	0.3	0.6	0.3	0.7	0.2

Values are reported as Mean ± SD. Abbreviations: MO-Motor Observation; SD-Standard Deviation. AAR-Antagonist-Agonist Ratio; NME-Neuromuscular Efficiency

5.Discussion

This study explored the effects of motor observation, together with verbal instruction, on muscle activity and torque production in response to acute isokinetic resistance exercise. Based on previous research, it was hypothesized that supplementing verbal internal focus with motor observation could lead to higher muscle activity and torque production (vs. verbal internal focus alone). Overall, the present results suggest that motor observation has no additional effect on torque, work output, fatigue, antagonist-agonist ratio, or neuromuscular efficiency compared to that seen when using internally focused verbal instruction alone during the performance of 6 sets of 10 repetitions of maximal isokinetic leg extensions at 90º/s.

Muscle fatigue is manifested as a decrease in torque or power output in response to repeated or prolonged muscle contractions (42). During high-intensity contractions, metabolic changes within the muscles, such as increased levels of inorganic phosphate, H^+, and adenosine diphosphate, can reduce the conduction velocity of tissue depolarization which can be manifested as altered EMG signal (amplitude and frequency domain) (42,43). Additionally, increases in inorganic phosphate have been shown to decrease isometric force and fiber stiffness. This particular metabolite, together with H^+, has also been shown to be associated with an early drop in torque production in response to muscle contraction. In particular, the combined effect of both these metabolic products is additive and promotes a direct inhibition of torque by means of a reduced Ca^{2+} sensitivity (42). Some factors may explain the inexistence of differences between conditions in our study. Previous research suggests that alterations in motor unit recruitment pattern due to fatigue can limit the efficacy of verbal instructions to increase sEMG activity(7). For instance, in a study that explored the effects of verbal instruction on muscle activation during a set of seated row performed until failure (at 70% of 1RM), the authors reported a 15.2% increase in the latissimus dorsi activity and a 14.4% reduction in the posterior deltoid during the initial repetitions of the set. In contrast, no between muscle differences in activation were observed during the terminal repetitions of the set. (7). Therefore, it is possible that fatigue accumulation during a set preformed to volitional failure down regulates the effect of attentional focus and motor observation on sEMG.

Some characteristics of exercise, such as the type, velocity and intensity of contraction are known to influence the effects of attentional focus strategies on sEMG activity and torque production. Exercise intensity, in particular, seems to have an important influence on the efficacy of different attentional focus strategies on sEMG activity(5,9). A study examining the effects of different internal focus conditions during the bench press at different intensities reported an increased activity of the pectoralis major at 50 and 80% 1RM with chest focused verbal instructions. Conversely, for the triceps brachii, the use of triceps focused verbal instructions was associated with increased EMG activity at 50, but not at 80% 1RM (9). In addition, although an increased activity was also seen for the pectoralis major in the 80% 1RM condition, it is important to note that the magnitude of this effect (vs. a control condition) was lower than that obtained at 50% 1RM (13.3 vs. 22%, effect size: 0.19 vs. 0.43). These findings strongly suggest that exercise intensity can modulate the interaction between the internal focus of attention and sEMG, and that this effect can be differently manifested depending on the analysed muscle. In this regard, for the bench press exercise, another report even suggested the existence of an intensity threshold for the loss of a focus effect around 60-to-80% 1RM (5). In this study the authors found that focusing on using either the pectoralis major or the triceps brachii increased the amplitude of sEMG at loads between 20% 1RM and 60% 1RM, but not at 80% 1RM. These findings are relevant when considering isokinetic exercise. This exercise paradigm requires maximal individual effort against the lever arm in each repetition. Thus, the intensity of contraction is always maximal and consequently above the suggested threshold of intensity between 60-80% 1RM. For this reason, the isokinetic mode of contraction might result in a smaller effect of attentional focus instructions and possibly of motor observation on exercise performance.

Contrasting to the contention that isokinetic exercise attenuates the relationship between internal focus and muscle activation, a previous study (3) reported that attentional focus instructions affected quadriceps EMG activity during a single set of 10 repetitions of isokinetic leg extensions at 60º/s (although no effect was found for force production). In this study, internally focused verbal instructions led to higher integral EMG (iEMG) of the quadriceps muscle compared to externally focused instructions. Conversely, an external focus led to a more efficient exercise performance (i.e. equal torque production with lower iEMG activity), which ultimately agrees with the proposed constrained action hypothesis (1). In this regard, the speed of contraction seems to modulate the effect of attentional focus verbal instructions on muscle activity and torque production during isokinetic exercise. In a study that compared the effects of different attentional focus strategies on the performance of isokinetic elbow flexions at 3 different speeds, the authors found that the use of an external focus was associated with lower sEMG at all speeds. In addition, this focus modality resulted in higher torque production at 60º/s, but not at 180º/s or at 300º/s (44). Similar results were reported in an experimental design focusing on pectoralis major or the triceps brachii (i.e. internal focus conditions). In this study, the authors found higher amplitude of normalized EMG (nEMG) during the execution of the bench press exercise at a controlled, but not at an explosive speed (45). This suggests that a higher speed of contraction can attenuate the effect of attentional focus strategies on torque production. In our study, we prescribed a faster velocity of contraction compared to that used by Marchant & Greig (3) (90 vs. 60 º/s). We used a knee extension velocity similar to that used in another study evaluating the effects of isokinetic leg extension training on quadriceps sEMG (37). Since the effect of attentional focus strategies on torque production can be reduced at higher speeds of contraction, it is possible that this methodological difference can partially explain the contrasting results between our study and that of Marchant & Greig (3).

Moreover, it is possible that the effect of attentional focus instructions might depend on the muscle group being exercise(22). In a study that compared the effects of different attentional focus strategies during long term resistance training the authors reported a significant effect for increased muscle thickness of the elbow flexors favouring internal instructions, while no significant difference was shown for the quadriceps muscles.(22)

Another important point to mention is that some participants reported the feeling of a temporal asynchrony between the observed motor action in the video and the participants own execution during the set. This occurred despite the fact that both the video recording and the participants' execution were performed at a leg-extension velocity of 90º/s (and the concentric and eccentric phases being coordinated between the performer's execution and the video motor observation). The temporal lag was a consequence of slightly different tempos at the end of the concentric phase and may have partially masked any possible additive effects of motor observation on sEMG and torque production. The mechanistic basis of this effect may rely on the higher constrainment created by a conscious effort of the performer to match his performance to the observed motor action.

According to our findings, isokinetic exercise resulted in intra-set decreases in work output. In specific, reduced work output became significantly more pronounced after 4 sets of 10 maximal isokinetic repetitions and this occurred similarly between conditions as shown by the statistically significant differences in work output fatigue index starting between set 1 and set 4 through set #6 and between set #2 and #6. Interestingly, a significant difference between VM and RF EMG activity was also observed starting at set #4, which remained statistically significant until set #6. This was apparently due to slightly lower sEMG activity of the RF compared to VM. Taken together, these results suggest an association between lower RF activity and greater intra-set decreases in work output production during isokinetic leg extension training and that this effect is more pronounced after 4 sets of 10 maximal isokinetic repetitions.

A possible explanation for this could be the higher demand put on this muscle during this exercise by the fact that leg extension repetitions were completed in an open-chain fashion – well known to produce more RF activity, while closed-chain leg extension promotes higher vasti activity (46). Furthermore, other studies suggest that leg extension promotes higher RF activity compared to other exercises, such as the leg press and others (47–49). This further suggests that the exercise protocol used in the present study might have placed a higher demand on the RF muscle compared to the vasti. This fatigue build up would be expected to increase across sets, ultimately leading to this greater difference in activity between RF and VM in the last three sets (i.e. set 4, 5 and 6). Alternatively, the participants could have slightly reduced their range of motion due to fatigue build up in the last sets, therefore not reaching full extension (joint position in which the RF has been shown to be more active during open-chain compared to closed-chain exercises) (46). This would also explain the significant decrease in work output fatigue index in the same sets without significant decreases in peak torque or peak torque fatigue index.

Limitations

Finally, this study has some limitations. First, the sample size was calculated using the effect sizes of a study that compared externally vs internally focused instructions (3) and in this study only, we compared the use of motor observation on internally focused instructions and not internal vs external focused instructions per se. This may have compromised statistical power to detect significant effects between conditions. Second, the temporal asynchrony developed across the set could have created some interference on individual motor control, leading to motor containments, which could have "masked" a possible effect of motor observation on muscle activity and force production. Third, we did not include an externally focused verbal instruction condition neither a "no instruction" condition, which limits the comparison of these results to conditions such as externally focused verbal instructions or the absence of verbal instructions. Future studies should address these limitations

6.Conclusion

Taken together, these results suggest that motor observation has no additional effect on torque, work output, fatigue, antagonist-agonist ratio, or neuromuscular efficiency compared to the use of internally focused verbal instructions alone during the performance of 6 sets of 10 repetitions of maximal isokinetic leg extensions at 90º/s. Further studies exploring the effects of motor observation on muscular activity and torque production during resistance training are required to corroborate the observed results and should strive to have a larger number of participants to increase statistical power and conduct more robust statistical analyses.

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8.Annexes

Annex 1. Health screening questionnaire

Questionário Médico Pré-exercício

Toda informação fornecida é confidencial. Este questionário será útil para conhecermos melhor os seus hábitos de exercício físico e a sua saúde. Para garantir que não se insere em nenhum dos critérios de exclusão deverá responder todas as questões com toda a sinceridade.

Sujeito ID:____ Data: ________________

Data de Nascimento:_______________________

Masculino/Feminino:_______________________ Idade:________________

Questionário Médico

	Sim	Não
1. Costuma ter dores no peito enquanto repousa e/ou realiza esforço?	____	____
2. Se respondeu "Sim", o seu médico já diagnosticou estas dores?	____	____
3. Já sofreu um enfarte do miocárdio ou foi informado de quaisquer problemas cardíacos?	____	____
4. Caso a sua resposta seja "Sim", o enfarte ocorreu durante o último ano?	____	____
5. Já fez algum electrocardiograma? Se sim, quando?	____	____
6. Costuma ter hipertensão? (> 140/90 mmHg)	____	____
7. Se respondeu "Sim", está a controlar de alguma forma a sua pressão arterial elevada, por exemplo tomando medicamentos?	____	____
8. Já lhe foi diagnosticado colesterol elevado (hipercolesterolémia)	____	____
9. Costuma ter perda de equilíbrio devido a tonturas ou perdas de consciência?	____	____
10. O seu médico disse-lhe especificamente para não fazer exercício "severo" ou "pesado"?	____	____

Anamnese Clínica

Tem ou já teve: (marque X em caso afirmativo)

_____ Sopro cardíaco

_____ Extrassistolia/Pausas compensatórias

_____ Dor ou pressão no peito

_____ Hipertensão

_____ Enfarte agudo do miocárdio

_____ Acidente vascular cerebral (AVC)

_____ Arritmias

_____ Asma

_____ Bronquite

_____ Cancro

_____ Diabetes

_____ Enfisema pulmonar

(continuação)

_____ Cãibras nas pernas

_____ Varizes

_____ Tonturas/ desmaio

_____ Dor nas costas

_____ Falta de ar

_____ Lesões nas costas, joelhos ou tornozelos

_____ Epilepsia

_____ Pneumonia

_____ Febre reumática

_____ Escarlatina

_____ Intervenção cirúrgica

Explicações/comentários/Descrições:____

Outras doenças/lesões/problemas médicos:____

Medicamentos/medicamentos que está a tomar (Lista a dosagem por favor):________________

Anamnese Familiar

Por favor indique o número de parentes (mãe, pai, avós, irmãos) que têm ou tiveram as seguintes patologias:

Enfarte do miocárdio ou AVC antes dos 50 anos _____

Enfarte do miocárdio ou AVC depois dos 50 anos _____

Patologia cardíaca congénita _____

Cirúrgia cardiotorácica _____

Hipertensão arterial _____

Diabetes _____

Excesso de peso/obesidade _____

Hipercolesterolémia _____

Comentários:

Sintomatologia

Sente alguns dos seguintes sintomas durante a prática de exercício? (marque x em caso afirmativo)

_____ Dor no peito

_____ Falta de ar

_____ Palpitações

_____ Tosse durante o esforço

Hábitos de Tabagismo

Hábitos de fumador

Fuma tabaco diariamente? Sim_____ Não_____

Se sim, quantos por dia? <1/2 maço_____ ½ a 1 maço_____

1 -2 maços_____ >2 maços_____

Já fumou tabaco no passado e conseguiu deixar o hábito de fumador? Sim____ Não____

Quantos meses/anos passaram desde que deixou o hábito de fumar? _____

Quantos maços de tabaco fumava por dia antes de ter deixado de fumar? _____

Quantos anos fumou antes de parar de fumar? _____

Hábitos de Exercício/Actividade Física

1. É fisicamente activo?______________________________

   Se sim, que tipo de actividade pratica regularmente? ______________________________

2. Quantas vezes por semana pratica actividade física? ______________________
3. Durante quantos minutos pratica actividade física? ____________________
4. Qual a intensidade do seu exercício? (Assinale uma opção)

   Baixo Moderado Elevado

5. Desde há quanto tempo (em anos) se considera fisicamente activo?______________________

Annex 2. Physical activity questionnaire

Adaptado de “The Aerobics Center Longitudinal Study Physical Activity Questionnaire.”

Nome/ID: ____
Idade: ______ Sexo: ________________ Data Nascimento ___/___/_____
Data ___/___/_____

Nesta secção, gostaríamos de lhe colocar questões sobre os seus hábitos semanais de atividade física e exercício físico. Por favor, responda da forma mais precisa e honesta possível. Coloque uma cruz nos respetivos quadrados de resposta, ou escreva um número específico sempre que pedido.

Exercício/Atividade física

1. Nos últimos três meses, quais das seguintes atividades moderadas ou vigorosas praticou regularmente? (por favor, coloque uma cruz no quadrado de resposta SIM ou NÃO em função do que mais se aplique ao seu caso; faculte uma estimativa da quantidade de atividade para todas as respostas assinaladas com SIM.) Seja o mais completo possível.

Caminhar

☐ NÃO
☐ SIM
Quantas sessões por semana? _____
Quantos Quilómetros (ou metros) por sessão? _____
Duração média por sessão? _____ (minutos)
Qual é o seu ritmo habitual de caminhada? (Por favor, coloque uma cruz na resposta)

☐ Casual ou passeando (<3 km/h)
☐ Médio ou normal (3 a 5 km/h)
☐ Bastante rápido (5 a 6.4 km/h)
☐ Rápido ou passada larga (6.5 km/h ou mais rápido)
☐

Subir escadas

☐ NÃO
☐ SIM
Quantos lances de escadas sobe por dia? (1 lance = 10 escadas) _____

***Jogging* ou Corrida**

☐ NÃO
☐ SIM
Quantas sessões por semana? _____
Quantos quilómetros (ou metros) por sessão? _____
Duração média por sessão? _____ (minutos)

Passadeira

☐ NÃO
☐ SIM
Quantas sessões por semana? _____

Duração média por sessão? _____ (minutos)
Velocidade? _____ (km/h) Inclinação? _____ (%)

Bicicleta

☐ NÃO
☐ SIM
Quantas sessões por semana? _____
Quantos quilómetros por sessão? _____
Duração média por sessão? _____ (minutos)

Natação NÃO

☐ SIM
☐ Quantas sessões por semana? _____
Quantos quilómetros por sessão? _____
Duração média por sessão? _____ (minutos)

Dança / Calisténicos / Exercício no chão

☐ NÃO
☐ SIM
Quantas sessões por semana? _____
Duração média por sessão? _____ (minutos)

Desportos moderados (p.e. Voleibol de lazer, golfe, danças sociais, ténis de pares)

☐ NÃO
☐ SIM
Quantas sessões por semana? _____
Duração média por sessão? _____ (minutos)

Desportos vigorosos de raquete (p.e. ténis)

☐ NÃO
☐ SIM
Quantas sessões por semana? _____
Duração média por sessão? _____ (minutos)

Outros desportos vigorosos ou exercício que envolva corrida (p.e. Basquetebol, Futebol)

☐ NÃO
☐ SIM, especifique qual: ___________________________
Quantas sessões por semana? _____
Duração média por sessão? _____ (minutos)

Outras atividades

☐ NÃO
☐ SIM, especifique qual: ___________________________
Quantas sessões por semana? _____
Duração média por sessão? _____ (minutos)

Treino de Força (máquinas, pesos livres ou outro)
☐ NÃO
☐ SIM
Quantas sessões por semana? _____
Duração média por sessão? _____ (minutos)

Tarefas domésticas (p.e. varrer, aspirar, lavar roupa, esfregar o chão)
☐ NÃO
☐ SIM
Quantas horas por semana? _____

Jardinagem
☐ NÃO
☐ SIM
Quantas horas por semana? _____

2. Quantas vezes por semana pratica atividade física vigorosa que se acompanhe de aumento dos níveis de sudação? ________________ (vezes por semana).

Cálculos:

O score é feito atribuindo determinados valores de MET às atividades acima descritas.

Os scores podem ainda ser convertidos em Quilocalorias.

(sessões/semana) x (min/sessão) x (h/min) x (METs) = MET-h/semana

Por exemplo,

Bicicleta (4.0 MET): 3 sessões/semana, 16km/sessão, 30min/sessão

Natação (10.0 MET): 2 sessões/semana, 1,6km/sessão, 60min/sessão

Bicicleta: (3 sessões/semana) x (30min/sessão) x (1h\60min x 4.0METs) = 6.0 MET-h/semana

Natação: (2 sessões/semana) x (60min/sessão) x (1h/60min x 10.0METs) = 20.0 MET-h/semana TOTAL = 26.0 MET –h/semana

Annex 3. Waterloo limb-dominance questionnaire

Questionário de dominância pedal de Waterloo (versão revista)

Instruções: por favor, responda a cada uma das seguintes questões com sinceridade. Desenhe um círculo em volta de **SD (Sempre Destro)** ou **SE (Sempre Esquerdino)**, caso desempenhe cada uma das tarefas listadas recorrendo *sempre* ao mesmo pé. Caso recorra *habitualmente* mais a um do que ao outro pé, circule **HD (Habitualmente Destro)** ou **HE (Habitualmente Esquerdino)** em conformidade com o que melhor se enquadra no seu caso. Se recorre a ambos os pés de forma indiscriminada para a realização das tarefas em causa, circule a opção **AB (Ambidestro)**.

Não se limite a desenhar círculos para cada uma das questões. Imagine-se, tanto quanto possível, a realizar cada uma das tarefas listadas antes de selecionar a opção mais correta. Se necessário, pare de realizar o questionário e simule gestualmente a tarefa apresentada em cada uma das linhas da tabela.

1. Que pé utilizaria para rematar uma bola, a partir de uma posição estacionária, em direção a um alvo que se encontra mesmo à sua frente?	SE	HE	AB	HD	SD
2. A que pé recorreria se tivesse que permanecer parado em apoio unipedal (pé coxinho)?	SE	HE	AB	HD	SD
3. Se tivesse de alisar areia da praia com um dos seus pés, qual escolheria?	SE	HE	AB	HD	SD
4. Se tivesse de subir para uma cadeira, que pé utilizaria em 1º lugar?	SE	HE	AB	HD	SD
5. Se tivesse de pisar um inseto voador que se desloca rapidamente pelo chão de sua casa, que pé utilizaria?	SE	HE	AB	HD	SD
6. Se tivesse que permanecer em equilíbrio unipedal (pé coxinho) sobre uma linha de comboio, que pé utilizaria?	SE	HE	AB	HD	SD
7. Se quisesse apanhar um berlinde recorrendo a um dos seus pés, qual utilizaria?	SE	HE	AB	HD	SD
8. Se tivesse de saltar ao pé coxinho, qual pé utilizaria?	SE	HE	AB	HD	SD
9. Se tivesse de enterrar uma pá no chão para escavar um buraco, que pé utilizaria para fazer força sobre a pá?	SE	HE	AB	HD	SD
10. Quando permanece por longos períodos de tempo em pé, maioria das pessoas tende a deslocar o seu peso para uma perna enquanto o joelho contrário é repousado em flexão. Nestas condições, sobre que perna tende a fazer incidir a maior parte do seu peso?	SE	HE	AB	HD	SD
11. Existe algum motivo (e.g. lesão) que o tenha forçado a alterar a sua preferência pedal para alguma das tarefas acima listadas?	Sim				Não
12. Alguma vez foi encorajado (treinado) a utilizar preferencialmente um ou outro pé em contextos particulares?	Sim				Não