Bilateral heel-rise test performance and physiological response are influenced by cadence and ankle position

O desempenho e as respostas fisiológicas ao teste de elevação do calcanhar bipodal são influenciados pela cadência e posição dos tornozelos

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ABSTRACT | INTRODUCTION: Different heel-rise test (HRT) protocols have been used, possibly leading to varied responses. It is necessary to analyse the impact of protocol variation on test responses. **PURPOSE:** To compare the performance, muscle oxygenation (MO), and heart rate (HR) responses of adults in bilateral HRT protocols. **METHODS:** This was a cross-sectional crossover study. Thirty participants (23.1±2.9 years; 16 men) performed four bilateral HRT protocols with varying cadence (self-cadenced; externally cadenced) and ankle position (neutral; dorsiflexion). For MO responses, we analysed tissue oxygen saturation (StO_2) and oxyhemoglobin concentration variation ($\Delta[O_2Hb]$) and calculated the variation between the smallest and final values (ΔNadir-Final) and the area under the curve (AUC). The variation between the initial and final HR values (ΔHR) and the time constant (τ) were calculated. Friedman's test was used to compare the variables among the protocols. Two-way ANOVA was used to identify the impact of cadence and/or ankle position. **RESULTS:** The number of repetitions and execution time were higher in the neutral position and externally cadenced protocols (p<0.001 for both). ΔNadir-Final (StO_2: p<0.001; $\Delta[O_2Hb]$: p=0.005) and AUC (StO_2: p<0.001; $\Delta[O_2Hb]$: p<0.001) of both MO variables were higher in the neutral position protocols. Self-cadenced protocols presented higher HR increase and faster τ (p=0.006 and p=0.046). **CONCLUSION:** Bilateral HRT performed in a neutral position, and external cadence promotes more repetitions and a longer execution time. Dorsiflexion promotes lower muscle reperfusion, and self-cadence higher and faster HR increase.

KEYWORDS: Physical Functional Performance. Muscle fatigue. Oxyhemoglobin. Heart Rate. Heel-Rise Test.

RESUMO | INTRODUÇÃO: Diferentes protocolos do teste de elevação do calcanhar (TEC) têm sido utilizados, sendo necessário analisar o impacto das variações nas respostas do teste. **OBJETIVO:** Comparar o desempenho e respostas de oxigenação muscular (OM) e frequência cardíaca (FC) de adultos em diferentes protocolos do TEC bipodal. **MATERIAIS E MÉTODOS:** Este foi um estudo transversal do tipo cruzado. Trinta participantes (23,1±2,9 anos; 16 homens) realizaram quatro protocolos do TEC bipodal, variando cadenciamento (autocadenciado e cadenciado externamente) e posição dos tornozelos (neutra e dorsiflexão). Para a OM, analisamos a saturação tecidual de oxigênio (StO_2) e variação da concentração de oxihemoglobina ($\Delta[O_2Hb]$) e calculamos a variação entre os menores valores e os valores finais (ΔNadir-Final) e área sob a curva (AUC). Para a FC, calculamos a variação dos valores iniciais e finais (ΔFC) e constante de tempo (τ). O teste de Friedman foi utilizado para comparar as variáveis entre os protocolos. A ANOVA de dois fatores foi utilizada para identificar o impacto da cadência e/ou posição dos tornozelos. **RESULTADOS:** O número de repetições e o tempo de execução foram maiores nos protocolos em posição neutra e cadenciado externamente (p<0,001 para ambos). ΔNadir-Final (StO_2: p<0,001; $\Delta[O_2Hb]$: p=0,005) e AUC (StO_2: p<0,001; $\Delta[O_2Hb]$: p<0,001) de ambas as variáveis de OM foram maiores nos protocolos em posição neutra. Protocolos autocadenciados apresentaram maior aumento da FC e τ mais rápida (p=0,006 e p=0,046). **CONCLUSÃO:** O TEC realizado em posição neutra e cadenciamento externo gera maiores repetições e tempo de execução. A dorsiflexão promoveu menor reperfusão muscular e o autocadenciamento, maior e mais rápido aumento da FC.

PALAVRAS-CHAVE: Desempenho Físico Funcional. Fadiga Muscular. Oxihemoglobina. Frequência cardíaca. Teste de Elevação do Calcanhar.

Introduction

The heel-rise test (HRT) consists of performing successive plantar flexion until mechanical failure in movement.[1,2] Owing to its operational ease and low cost, HRT has been widely used in clinical practice to assess the functionality of the triceps surae muscle group in patients undergoing orthopaedic, neurological, or cardiovascular rehabilitation.[2-5] However, its applicability is still limited due to the lack of a standard protocol, as countless variations exist in the literature.[6]

Hebert-Losier et al.[3] mentioned that the position of the feet, range of motion, cadence, and use of the arms to balance are the main factors that differentiate the protocols. Another important factor in the performance of the HRT is the type of support used by the individual. Usually, unipedal support has been used in orthopaedic and neurological assessments[7], and bipedal support has been used for cardiovascular assessments.[8] According to Monteiro et al.[2], bilateral HRT is more reliable for assessing muscle fatigue because it minimises balance-related problems. However, the influence of such factors on performance and physiological alterations induced by the test is unclear.

A large part of the discussion is centred on theoretical models.[3,6] Svantesson et al.[5] demonstrated that HRT performed until exhaustion induced fatigue in the triceps surae muscle group. Other authors have concluded that HRT is a valid, reliable, and easily applicable test for assessing peripheral muscle fatigue.[4,5] Since then, researchers have begun to investigate the association of HRT with clinical outcomes[2-5,8] and have developed reference values.[1,9] However, little attention has been given to the physiological alterations that this test causes.

The influence of intervening factors and physiological stress analysis caused by different protocols would allow knowledge elucidation of HRT. Therefore, the objective of this study was to compare performance (number of repetitions and test time), physiological (muscle oxygenation and heart rate - HR), and subjective (perception of effort and fatigue) variables between four different bilateral HRT protocols in healthy adults with the purpose of identifying the physiological behaviour of these variables during HRT.

Methods

The present crossover-type cross-sectional study was previously approved by the Human Research Ethics Committee (CAAE 07741919.0.0000.0118). All individuals were informed of the protocols and signed the consent form in agreement with Resolution 466/12 of the National Health Council.

Subjects

Apparently healthy adults aged between 18 and 35 years were selected using convenience sampling (non-probabilistic). Participants who reported the presence of cardiovascular, neurological, or musculoskeletal diseases or injuries that interfered with the execution of the protocols were excluded from the study. Recruitment was conducted from April to October 2019 through direct contact and social media.

Study design

Each participant performed all four different HRT protocols, one on each day, seven days apart. Participants were asked to avoid physical exercise before each assessment. To avoid a potential source of bias, all procedures were performed at the same time of the day and were preceded by a rest period of at least 10 minutes. The study design is illustrated in Figure 1. Anamnesis and anthropometric assessments were conducted on the first day of the study before the application of the first test.

Figure 1. Study design flowchart
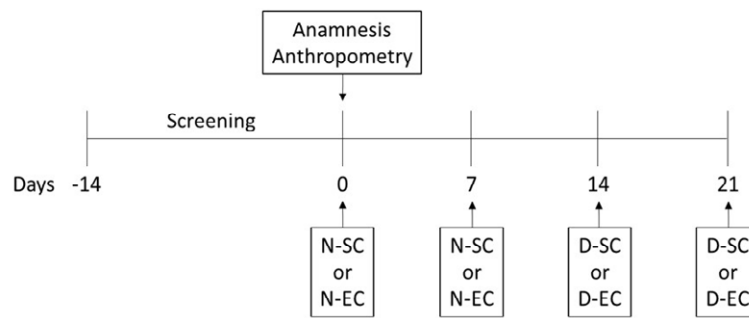
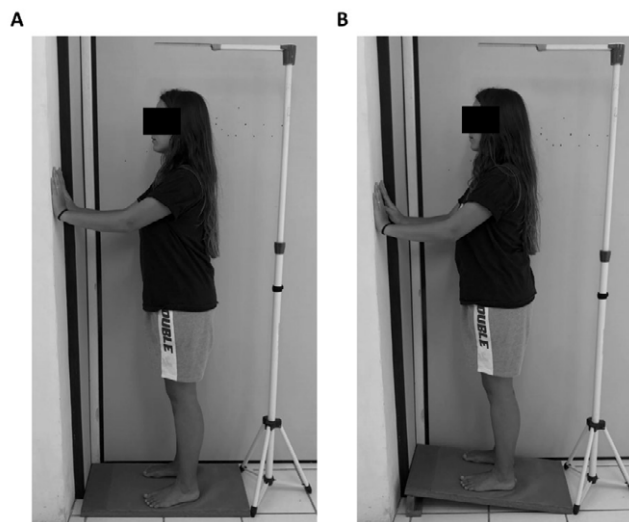Source: The authors (2022).

Anthropometric assessments

Body mass was measured using a digital scale with the participants barefoot, and height was measured using a portable stadiometer. Subsequently, body mass index (BMI) was calculated as the ratio of body mass (kg) to squared height (m²).

Heel rise test

The HRT protocols were divided according to ankle position (neutral or dorsiflexion) and cadence (self-cadence or external cadence), totalling four protocols: neutral and self-cadence (N-SC), neutral and external cadence (N-EC), dorsiflexion and self-cadence (D-SC) and dorsiflexion and external cadence (D-EC). During the pilot study, the participants reported more delayed-onset muscle soreness after the protocols with dorsiflexion. Therefore, to reduce the influence of muscle pain, protocols with a neutral ankle position were administered on days 1 and 2. The cadence was randomised in a simple manner.

To execute the protocols, the individuals remained in the orthostatic position and bipedal support over a wooden platform, facing the wall with both hands resting on it. Figure 2 illustrates the ankle positions for each protocol. In summary, the platform remained parallel to the ground in the neutral protocols and at an inclination of 10° in the dorsiflexion protocols (the angle was confirmed using a goniometer). The tests were performed until fatigue was reached, as previously described.[1,4] The maximum number of repetitions and total test time were measured. These data were used to calculate the repetition rates.

Figure 2. Heel-rise test protocols positioning. A: neutral ankle position. B: dorsiflexion ankle position

Source: The authors (2022).

The test cadence was adjusted to one repetition per second (rep/s) and conducted using a digital metronome in the external cadence protocols.[9] Free cadence (fastest possible) was adopted in the self-cadenced protocols. Muscle oxygenation and heart rate were recorded during the entire procedure. At the end of each test, individuals were asked about their subjective perception of effort (SPE) and leg fatigue (SPLF).

Muscle oxygenation

Oxygenation data were measured using a near-infrared spectroscopy (NIRS) device. The optodes and receptor were positioned at the medial gastrocnemius muscle belly of the dominant lower limb at fixed intervals.[10] The wavelength was adjusted between 760 and 850 nm. The sampling frequency was 10 Hz, and data were smoothened by applying an eight-point moving average filter using Oxysoft software (Artinis Medical Systems, Holland). We extracted tissue oxygen saturation (StO_2) and oxyhemoglobin concentration variation ($\Delta[O_2Hb]$) data and calculated the area under the curve (AUC), as previously described.[11] The variation in StO_2 (ΔStO_2), the lowest obtained values (Nadir), and the variation in Nadir for the final values (ΔNadir-Final) were also calculated.

Heart rate

To assess the HR kinetic, we used a pulse monitor RS800CX (Polar®, Finland) with a beat-to-beat recording (RR intervals). The signals were transmitted to the provided software and smoothened using an eight-point moving-average filter. We used high- and low-pass filters of two standard deviations to determine the amplitude and variation of the HR (ΔHR), in addition to the time constant (τ) predicted by a previously described monoexponential equation.[12,13] The software CardioKin 1.2 (Brazil) was used to obtain the data.

Subjective perception of effort and leg fatigue

The modified Borg scale was used to assess subjective perceptions.[14] Participants were asked at the beginning and end of the HRT tests about SPE and SPLF. The variations (ΔSPE and ΔSPLF) were determined by subtracting the final values from the initial values.

Statistical analysis

A pilot study was performed to identify the minimum number of participants included in the sample. Considering the number of repetitions obtained in each protocol (N-SC 96.4 ± 40.1 reps; N-EC 104.6 ± 73.1 reps; D-SC 80.0 ± 36.0 reps; D-EC 67.0 ± 21.7 reps), with a 5% bidirectional error probability and an 80% effect size, the need to include 27 individuals in the sample was observed.

Data were extracted into electronic spreadsheets and analysed using SPSS Statistics 20.0 (IBM, United States of America). The Shapiro-Wilk test was used to verify the data distribution. The Friedman test, followed by Bonferroni post-hoc correction, was used to compare the variables of interest. A two-factor analysis of variance (ANOVA) was used to determine the influence of cadence, ankle position, and their interaction on physiological and performance responses. We considered 95% confidence for statistical analysis ($p<0.05$). Data are expressed as mean and standard deviation or median and interquartile interval.

Results

Thirty-one individuals agreed to participate in the study and performed all the procedures. One participant was excluded because of failure to capture tissue oxygenation data. The final sample was mostly composed of men (53%); the mean age was 23.1±2.9 years, and the BMI was 24.3±3.2 kg/m^2. Table 1 presents the results for performance, HR kinetics and SPE and SPLF. Table 2 summarises the tissue oxygenation data. There was no difference in ΔSPE (p=0.609) or ΔSPLF (p=0.558) among the protocols.

Table 1. Performance, heart rate kinetics and subjective perception of effort and leg fatigue comparisons among different heel-rise test protocols

	N-SC	N-EC	D-SC	D-EC	Friedman p-value	Two-way ANOVA Cadence	Position	Interaction
Repetitions, n	90.7 ± 49.7	103.1 ± 66.9	67.9 ± 34.4*#	80.4 ± 60.8*#	<0.001	0.214	0.024	0.995
Time, s	85.9 ± 56.2	105.3 ± 68.1	60.4 ± 25.2*#	83.7 ± 61.9#$	<0.001	0.037	0.022	0.846
Repetition rate, rep/s	1.15 ± 0.34	0.98 ± 0.06*	1.14 ± 0.33#	0.97 ± 0.97*$	0.035	<0.001	0.793	0.905
Baseline HR, bpm	87.7 ± 14.0	87.6 ± 12.8	87.1 ± 14.3	87.8 ± 9.3	0.660	-	-	-
Amplitude, bpm	43.1 ± 17.7	34.0 ± 12.4*	44.3 ± 15.1#	33.9 ± 12.5*$	0.024	0.004	0.853	0.819
ΔHR, bpm	39.8 ± 16.1	32.1 ± 14.7*	38.9 ± 11.0#	33.7 ± 17.0*$	0.006	0.019	0.893	0.650
τ, s	19.1 ± 10.6	40.2 ± 39.2*	21.5 ± 19.0#	31.6 ± 56.7#	0.046	0.033	0.668	0.448
ΔSPE, pts	2.0 (0.5-3.0)	2.0 (0-4.0)	2.0 (0.5-3.0)	2.0 (0.5-3.0)	0.609	0.962	0.848	0.388
ΔSPLF, pts	4.5 (4.0-5.25)	4.5 (3.75-6.0)	5.0 (3.87-6.12)	4.75 (3.0-6.6)	0.558	0.813	0.705	0.508

N-SC, neutral position, and self-cadenced protocol. N-EC, neutral position, and externally cadenced protocol. D-SC, dorsiflexion position, and self-cadenced protocol. D-EC, dorsiflexion position, and externally cadenced protocol. rep/s, repetitions per second. HR, heart rate. ΔHR, heart rate variation. bpm, beats per minute. τ, time constant. ΔSPE, subjective perception of effort variation. ΔSPLF, subjective perception of leg fatigue variation. Data expressed in average ± standard deviation or median (interquartile range).
*$p<0.05$ vs. N-SC.
#$p<0.05$ vs. N-EC.
$$p<0.05$ vs. D-SC.
Source: The authors (2022).

Table 2. Muscle oxygenation among different heel-rise protocols

	N-SC	N-EC	D-SC	D-EC	Friedman p-value	Two-way ANOVA		
						Cadence	Position	Interaction
StO$_2$ Baseline (%)	69.4 ± 5.0	68.9 ± 5.0	68.0 ± 4.68	68.1 ± 6.0	0.856	-	-	-
Δ[O$_2$Hb] Baseline (µmol)	1.06 ± 1.08	0.54 ± 1.47	1.21 ± 1.20	0.88 ± 1.33	0.164	-	-	-
NadirStO$_2$(%)	51.2 ± 11.0	49.6 ± 10.4	51.9 ± 9.8	51.5 ± 10.3	0.362	0.599	0.495	0.735
Nadir Δ[O$_2$Hb] (µmol)	-21.0 ± 10.2	-21.2 ± 12.5	-19.3 ± 8.3[#]	-19.5 ± 9.1	0.015	0.894	0.252	0.817
ΔStO$_2$ (pp)	-18.2 ± 7.4	-18.0 ± 9.8	-16.1 ± 6.5[#]	-16.7 ± 7.2	0.029	0.884	0.363	0.992
ΔNadir-Final StO$_2$ (pp)	6.8 ± 3.7	6.0 ± 3.2	4.4 ± 4.0*[#]	5.2 ± 4.4*[#]	<0.001	0.973	0.027	0.259
ΔNadir-Final O$_2$Hb (µmol)	11.4 ± 7.9	10.4 ± 7.6	8.6 ± 7.2*[#]	9.9 ± 7.5	0.005	0.912	0.232	0.439
AUC StO$_2$ (%/s) x 1,000	48.51 ± 26.86	53.77 ± 33.39	33.14 ± 12.26*[#]	43.76 ± 26.00 [#$]	<0.001	0.095	0.008	0.571
AUC O$_2$Hb (µmol/s) x 1,000	11.96 ± 9.64	17.52 ± 16.27*	7.86 ± 5.38*[#]	10.98 ± 11.91[#]	<0.001	0.041	0.012	0.563

N-SC, neutral position and self-cadenced protocol. N-EC, neutral position and externally cadenced protocol. D-SC, dorsiflexion position and self-cadenced protocol. D-EC, dorsiflexion position and externally cadenced protocol. StO$_2$, tissue oxygen saturation. Δ[O$_2$Hb], oxyhemoglobin concentration variation. µmol, micromol. ΔStO$_2$, tissue oxygen saturation variation. ΔNadir-Final, variation of the lowest values to the final values. pp, percentual points. AUC, area under the curve. Data expressed in average ± standard deviation.
*p<0.05 vs. N-SC.
#p<0.05 vs. N-EC.
$p<0.05 vs. D-SC.
Source: The authors (2022).

Performance measures

A greater number of repetitions was observed in the protocols with neutral ankle position, impacted by ankle position (p=0.024). Both protocols in dorsiflexion were executed for a shorter duration than the N-EC, and this variable was impacted by cadence (p=0.037) and position (p=0.022). The execution time of D-SC was shorter than those of N-SC (p=0.022) and D-EC (p=0.037). Repetition rates were superior in the self-cadenced protocols for both ankle positions (p<0.001).

Muscle oxygenation

There was no difference in the baseline values of StO_2 (p=0.856), $\Delta[O_2Hb]$ (p=0.164), or Nadir StO_2 (p=0.362). Protocol D-SC showed Nadir $\Delta[O_2Hb]$ (p=0.015) and ΔStO_2 (p=0.029) values inferior to those of protocol N-EC. The ΔNadir-Final StO_2 (p=0.027), ΔNadir-Final O_2Hb (p=0.027), AUC StO_2 (p<0.001), and AUC O_2Hb (p<0.001) values were higher in the neutral position protocols than in their dorsiflexion pairs, except for protocol D-EC (ΔNadir-Final O_2Hb). In addition, AUC O_2Hb showed more significant values in protocol N-EC than in D-EC, with the influence of both cadence (p=0.041) and position (p=0.012).

Heart rate

The baseline HR was similar between the tests (p=0.660). Both amplitude (p=0.004) and ΔHR (p=0.019) were higher in the self-cadenced protocols than in the external cadence tests. Additionally, the N-EC group presented higher time constant values than the other groups (p=0.033).

Discussion

This is a pioneering study assessing muscle oxygenation and HR responses during HRT, as well as comparing the performance of different HRT protocols. This study demonstrated that bilateral HRT protocols provide different responses in the cardiovascular system and tissue oxygenation, which may be associated with performance variation. We also demonstrated that cadence may influence HR kinetics, and ankle position may influence peripheral muscle oxygenation levels.

Considering the number of repetitions as the main performance variable[1,3,7], we observed that the protocols in the neutral position showed better responses than those in the dorsiflexion position. This finding reinforces the observation by Hebert-Losier et al.[6] that ankle position during HRT may reduce the number of plantar flexions. Indeed, dorsiflexion provides a greater ankle range of motion. However, it increases the length of the muscle fibres of the triceps surae muscle group, harming the generation of torque with a consequent increase in muscle work.[6]

The test time was longer in the protocols without inclination and was influenced by ankle position and cadence. The greater muscle work imposed by the dorsiflexion position and the greater execution speed applied by the free cadence[3] demand greater muscle resistance, which promotes early muscle fatigue. Given that muscle fatigue is directly related to muscle resistance capacity, which is time-dependent[15], the protocols with a neutral inclination and external cadence may have caused a later point of voluntary fatigue, facilitating the mechanics of the movement and generating less work intensity.

In the present study, the repetition rate was higher in self-cadenced protocols. This behaviour was expected because the external cadence sought to standardise the HRT speed[3], providing less effort intensity. According to Hebert-Losier et al.[3], muscle work observed in self-cadenced protocols may lead to early fatigue.

Based on these findings, one may infer that external cadence and neutral position facilitated the performance of the test, reflecting on both more repetitions and longer execution times. Their clinical application may underestimate individuals because of less muscle work.

Regarding muscle oxygenation, all HRT protocols induced desaturation and deoxygenation (reduction in ΔStO_2 and Nadir$\Delta[O_2Hb]$). It is worth stressing that the N-EC and D-SC protocols showed differences in both variables. The N-EC protocol induced the greatest desaturation and deoxygenation during the test, demonstrating that the ankle position and cadence may affect the mechanics and intensity of the HRT, altering the muscle stress and inducing greater muscle consumption of oxygen, despite the absence of their influence on ΔStO_2 and Nadir$\Delta[O_2Hb]$.

A decrease in ΔStO_2 and $Nadir\Delta[O_2Hb]$ was expected, given the muscle effort induced during HRT, which may be considered a fatigue protocol.[3,16] Felici et al.[17] and Denis, Bringard, and Perry[10] demonstrated that StO_2 presents a constant decline in two phases during a fatigue protocol, one fast and the other slow, with stabilisation at the end, regardless of overload. However, in our study, StO_2 and $\Delta[O_2Hb]$ behaviours were different from those described by these authors, with an increase in their values after the Nadir, evinced by the increase in the variable ΔNadir-Final.

Luck et al.[18] found a similar StO_2 behaviour during triceps surae muscle group exercise. However, the exercise was cyclical, low intensity, with intervals (with one second of rest between contractions) and performed in the supine position[18], which differs from HRT. This observed increase may be associated with the progressive increase in local blood flow and the greater supply of oxygen to meet the energy demand. It is worth stressing that ΔNadir-Final was smaller in the protocols with dorsiflexion. The mechanical alteration stemming from the inclination of the feet may have led to muscle overload, influencing local reperfusion during the performance of the inclined protocols.

Moreover, the position directly influenced the AUC StO_2 and AUC $\Delta[O_2Hb]$, with smaller values in the inclined protocols. AUC assessment is a way to evaluate the dynamic behaviour of oxygenation variables, with larger areas indicating greater variation, translated as greater desaturation and deoxygenation.[11] In the present study, since both parameters were similar, the smaller AUCs obtained in the inclined protocols could stem from two factors: 1) smaller reperfusion after the Nadir and 2) shorter performance time of these protocols, generating fewer data.

In summary, ankle position directly influenced oxygenation variables related to local reperfusion. Dorsiflexion seems to cause more considerable muscle work[6], and the movement in a mechanical disadvantage caused by HRT in this situation may have generated a greater local oxygen demand, thus causing muscle bioenergetic responses that led to early fatigue and the finalisation of the test before that observed in the protocols executed in the neutral position.

The HR kinetics differed among the assessed protocols. Both the amplitude and ΔHR were superior in the free cadence protocols. Hence, it can be inferred that free-cadence protocols cause greater cardiac overload. This may be associated with the execution speed of these protocols. Speed may be considered a direct marker of exercise intensity during HRT.[1,3] In the face of more significant intensity, a gradual HR increment is necessary to supply metabolic demand.[13]

Another factor that supports the hypothesis of cadence as an intensity marker is the τ difference among the protocols. This marker represents a time constant and indicates the cardiovascular adjustment speed, with smaller values indicating greater adjustment speed.[13] In the present study, the self-cadenced protocols presented smaller τ values, indicating a faster HR increase. However, the greater τ values observed in the external cadence protocols may indicate a slower and progressive increase in HR during these variations.

Although differences were found in the performance, oxygenation, and HR variables, the SPE and SPLF proved similar. This finding may be related to the subjectivity of the instrument (CR10, Borg) as well as the sensation of similar difficulty in performing the protocols. It is worth emphasising that all tests resulted in increased SPE and SPLF values. The balance between the effort intensity and execution time may have contributed to this response.

Limitations

The main limitation of this study is related to our sample of healthy individuals. Although healthy adults are usually not the target subjects in clinical practice, knowing the normal physiological behaviour of these variables is necessary to perform future studies with other age groups and/or with orthopaedic, neurological, and cardiovascular alterations. In addition, our findings clearly show an interdependency between physiological and performance variables upon applying different HRT protocols.

Conclusion

Protocols in the neutral position with the use of external cadence enable more repetitions and longer HRT execution times in healthy adults, augmenting test performance. In addition, dorsiflexion induced less muscle reperfusion, whereas self-cadence led to greater cardiac overload. Therefore, protocol choice is a determinant of patient performance and response in clinical practice. Thus, it is necessary to consider the influence of cadence and ankle position on performance and physiological variables.

Authors' contributions

Silveira LS participated in the design of the research question, methodological design, data collection formulation, data collection procedure, data extraction and analysis, interpretation of results, and writing of the scientific article. Mortimer FM, Roque ABAO, and Martins EM participated in the data collection procedure, data analysis, and interpretation of results. Sonza A participated in the formulation of data collection, interpretation of results, research supervision, and review of the scientific article. Karsten M participated in the design of the research question, methodological design, formulation of data collection, interpretation of the result, supervision of the research, and review of the scientific article.

Conflicts of interest

No financial, legal or political conflicts involving third parties (government, companies and private foundations, etc.) were declared for any aspect of the submitted work (including, but not limited to grants and funding, participation in an advisory board, study design, preparation manuscript, statistical analysis, etc.).

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