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Original Articles

Beyond the slope: effects of downhill running on muscle function and recovery

Além da inclinação: efeitos da corrida em declive na função e recuperação muscular

Más allá de la inclinación: efectos de la carrera cuesta abajo en la función muscular y la recuperación

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Keywords:
Muscle damage; Echo intensity; Delayed onset muscle soreness; Hamstring-to-quadriceps ratio.

ABSTRACT
The study evaluated 17 men who underwent 6 sets of 5 min downhill running (-3°, 70% of maximal aerobic speed). Before, immediately after, 24 hours, 48 hours and 72 hours after the echo-intensity (EI) of the vastus lateralis (VL) and rectus femoris (RF), the muscle pain scale (DOMS), the concentric and eccentric peak torque (PT) were evaluated for subsequent calculation of the hamstring/quadriceps (H/Q) ratios. The EI of VL and RF did not change significantly (p>0.05). DOMS increased in VL and RF between 24 and 72 h (p=0.001-0.002). The PT of the extensors decreased immediately and remained lower for 24 hours (p=0.000-0.011). The conventional H/Q ratio increased at 24 hours (p=0.043), while the functional ratio decreased immediately after exercise (p=0.020), indicating transient muscle imbalance.

Palavras-chave:
Dano muscular; Eco-intensidade; Dor muscular de início tardio; Razão ísquios/quadríceps.

RESUMO
O estudo avaliou 17 homens que foram submetidos a 6 séries de 5 min de corrida em declive (-3°, 70% da velocidade aeróbica máxima). Antes, imediatamente após, 24h, 48h e 72h após foram avaliados a eco-intensidade (EI) do Vasto Lateral (VL) e Reto Femoral (RF), a escala de dor muscular (DOMS), o pico de torque (PT) concêntrico e excêntrico para posterior cálculo das razões isquiotibiais/quadríceps (H/Q). A EI do VL e RF não se alteraram significativamente (p>0,05). A DOMS aumentou no VL e RF entre 24 e 72h (p=0,001-0,002). O PT dos extensores reduziu imediatamente e permaneceu menor por 24h (p=0,000-0,011). A razão H/Q convencional aumentou às 24h (p=0,043), enquanto a razão funcional caiu imediatamente pós-exercício (p=0,020), indicando desequilíbrio muscular transitório.

Palabras clave:
Daño muscular; Intensidad del eco; Dolor muscular de aparición tardía; Relación isquiotibiales/cuádriceps.

RESUMEN
El estudio evaluó a 17 hombres que realizaron 6 series de 5 minutos de bajada (-3°, 70% de la velocidad aeróbica máxima). Antes, inmediatamente después, 24 horas, 48 horas y 72 horas después de la eco-intensidad (EI) del vasto lateral (VL) y del recto femoral (RF), se evaluaron la escala de dolor muscular (DOMS), el par máximo concéntrico y excéntrico (PT) para el cálculo posterior de las relaciones isquiotibiales/cuádriceps (H/Q). La IE de VL y RF no cambió significativamente (p>0,05). El DOMS aumentó en VL y RF entre 24 y 72 h (p=0,001-0,002). La PT de los extensores disminuyó inmediatamente y se mantuvo más baja durante 24 horas (p=0,000-0,011). La relación H/Q convencional aumentó a las 24 horas (p=0,043), mientras que la relación funcional disminuyó inmediatamente después del ejercicio (p=0,020), indicando un desequilibrio muscular transitorio.

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INTRODUCTION

Running is one of the most popular and accessible sports activities practiced by people around the world (van Poppel et al., 2021). The number of runners and running events has significantly grown in the last decades due mainly to its low cost and minimal equipment requirements (Vitti et al., 2020). Additionally, running contributes to a healthier lifestyle and is commonly performed in indoor environments (treadmills) or outdoor settings (tracks, streets, avenues, or parks). Noteworthy, outdoor environments often featuring inclines and declines (Scheer et al., 2020), this terrain variations result in a series of biomechanical and physiological adaptations for runners (Vernillo et al., 2017).

Downhill running is a whole-body exercise model used to investigate the physiological and biomechanical changes provoked by eccentric muscle actions and/or exercise-induced muscle damage (Bontemps et al., 2020). Downhill running efficiency is related to stretch-shortening cycle mechanism and is performed at submaximal intensity, which it can lead to a different pattern of fatigue and/or muscle damage when compared to run in flat terrains (Bontemps et al., 2020). In this way, downhill running can play a significant role in the occurrence of neuromuscular fatigue (primarily due to peripheral factors) and muscle damage. Among the main alterations resulting from muscle damage caused by downhill running are the elevation of intracellular proteins and enzymes, such as creatine kinase (CK) and lactate dehydrogenase (LDH) into the bloodstream, increased onset of delayed muscle soreness, reduction in range of motion, and diminished force production capacity (Clarkson and Hubal, 2002; Tricoli, 2001).

Regarding the reduction in strength caused by downhill running, it is observed that the knee extensor musculature is one of the most damaged (Eston et al., 1995), requiring 4 to 5 days for complete recovery (Bontemps et al., 2020), which may affect the H/Q ratio. Epidemiological studies have demonstrated that imbalances in the H/Q ratio play an important role in non-contact injuries to the thigh muscles and cruciate ligaments (Evangelidis et al., 2015; Taketomi et al., 2023). In this context, understanding the effects of downhill running on H/Q ratios, and in the case of alterations indicating an increased risk of injuries, comprehending the duration of these changes is of paramount importance for professionals involved in running training and rehabilitation routines. To the best of our knowledge, only one study (Assumpção et al., 2014), evaluated the effects of downhill running on the H/Q ratio. The authors concluded that downhill running (30 minutes, 70% vVO_2, -16%), despite causing a reduction in torque production after the run, did not significantly alter the H/Q ratio. However, the authors limited themselves to carrying out assessments of maximal isometric contractions of knee extensors and flexors. Furthermore, the authors evaluated peak isometric torque only before, immediately and 48h after downhill running. In this sense, a gap in the literature is identified, since the acute effects of downhill running on muscle quality, delayed onset muscle soreness, and especially the H/Q ratio are not known. Understanding these phenomena could be critical to develop strategies aiming reduce the risk of non-contact injuries, such as extending the recovery time between training sessions.

Our hypothesis is since due to the significant eccentric activity of the quadriceps during downhill running, the reduction in torque production capacity in this muscle group would be greater than in the knee flexors, thereby generating an imbalance in the H/Q ratios, increasing the risk of injury due to a temporary increase in joint instability. Therefore, the aim of this study was to investigate the effects of a downhill running protocol on the muscular quality, delayed onset muscle soreness (DOMS) and knee extensors and flexors torque ratio.

MATERIALS AND METHODS

PARTICIPANTS

The study included 17 physically active men (23,3 ± 2,4 years, 82 ± 14 kg, 173 ± 6 cm). All ethical procedures were approved by the institution where the study was conducted (CAAE: 65240622.9.0000.5020).). The inclusion criteria were: (a) being between 18 and 30 years old, (b) being physically active according to the IPAQ, (c) not having engaged in strength training in the three months preceding the study. The exclusion criteria were: (a) being a smoker, (b) having visible or known infectious or inflammatory diseases or processes, (c) a history of lower limb injury in the last 6 months, (d) using anti-inflammatory medications, herbal supplements, ergogenic substances such as creatine, arginine, and caffeine, or micronutrient supplements . The sample size was calculated using GPower 3.1 with the effect size (d = 0.71) derived from Assumpção et al. (2014), a minimum of 15 participants was required ($\alpha = 0.05$, power = 0.80). Initially, 20 participants were recruited, but only 17 participants completed all stages of the research. The reasons for giving up were: use of anti-inflammatory medication (n = 1) and not completing all stages of the research (n = 2).

EXPERIMENTAL DESIGN

The evaluation protocol involved 5 stages: 1) Assessment of muscular quality parameters through ultrasound; 2) Determination of specific Delayed Onset Muscle Soreness (DOMS) in the Vastus Lateralis (VL) and Rectus Femoris (RF) muscles using algometry; 3) Assessment of concentric and eccentric peak torque of the right knee extensors and flexors on an isokinetic dynamometer; 4) Conducting a maximal progressive treadmill test; 5) Performing a downhill running protocol (DRP). The stages, as well as the moments at which the

evaluations were performed, are described in Figure 1. All participants were instructed to refrain from engaging in physical activities and consuming alcoholic beverages throughout the study's duration.

ASSESSMENT PROTOCOL

STEP 1: EVALUATION OF MUSCULAR QUALITY PARAMETERS

All ultrasound imaging (US) assessments were conducted by a single experienced researcher. The images were taken after a 10-minute rest in the supine position. This procedure is necessary for the stabilization of body fluids. For muscular quality evaluation, the B-mode ultrasound system (Mindray DP30, China) was used with a linear-array probe operating at 32 Hz (60 mm, 7.5 MHz, depth of 6.0 cm, no image filter). The brightness and gain settings were standardized across all participants. Muscular quality was assessed by echo-intensity in the Vastus Lateralis (VL) and Rectus Femoris (RF) muscles. Three ultrasound images were obtained for each muscle with the subject at rest. The ultrasound probe was covered with water-soluble transmission gel and positioned longitudinally to the muscle fibers and perpendicular to the skin at 50% between the iliac crest and patella (RF, VL) (Baroni et al., 2013). The ultrasound images were analyzed using Image J software (National Institutes of Health, Bethesda, MD, USA). For both VL and RF, the criterion of positioning the largest possible rectangle (ROI) on the image of the muscle evaluated was always used and contact with aponeuroses should be avoided. Echointensity (EI) was determined according to the protocol proposed by Caresio et al., (2015). The average EI was determined using a standard grayscale histogram function and expressed as a value between 0 (black) and 255 (white), where values closer to 0 indicate higher muscular quality, while values closer to 255 indicate lower muscular quality.

STEP 2: SPECIFIC DOMS DETERMINATION

DOMS was quantified consistently by the same evaluator. The participant remained seated and indicated DOMS on a 10-point visual scale, where 0 (zero) represented the absence of pain and 10 (ten) represented excessive pain. Participants were asked about i) localized DOMS in the VL and RF muscle region after the evaluator applied pressure with a manual dynamometer at a force of 50N. A dynamometer (Instrutherm DD-200) with a resolution of 0.01 Newton and a flat tip of 1 cm^2 was used. The assessment points were marked with a dermatological pen to ensure measurements were taken at the same location each time (Reis et al., 2024).

STEP 3: TORQUE ASSESSMENT

Concentric and eccentric peak torque measurements were obtained for both knee extensors and flexors using an isokinetic dynamometer (Biodex

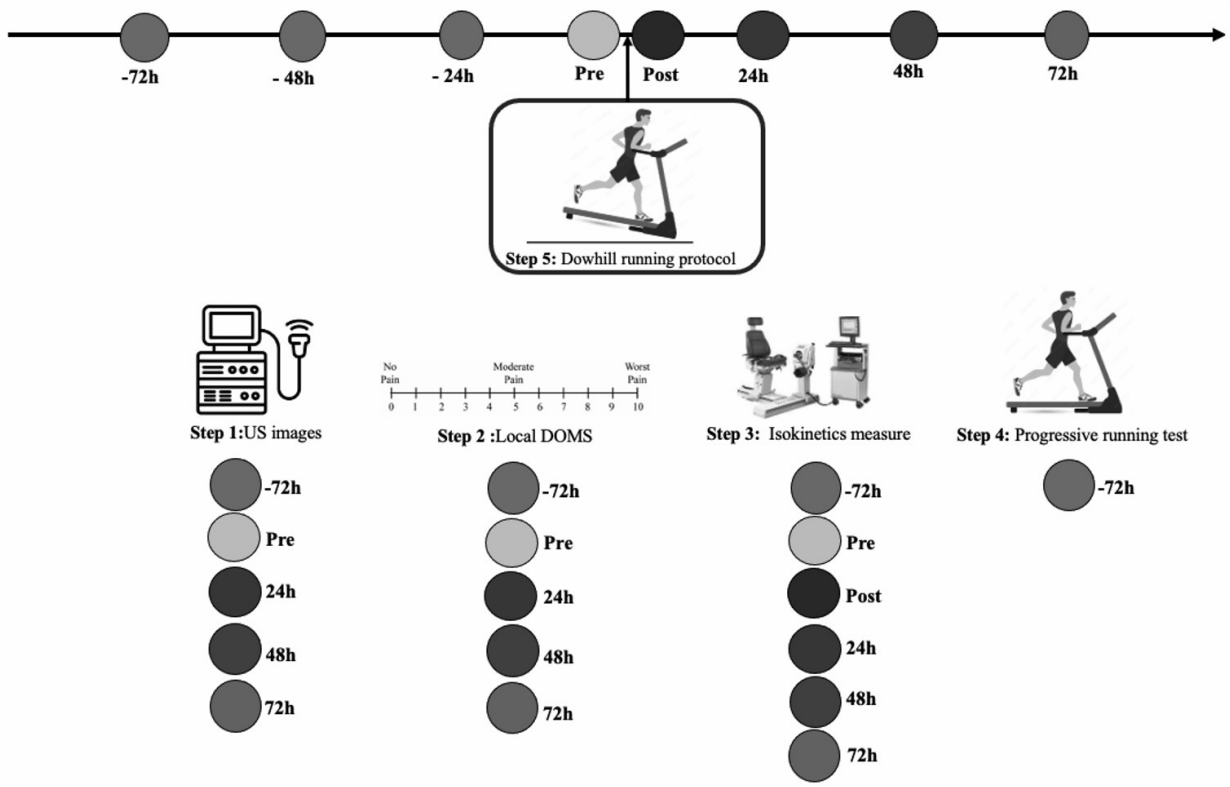

Figure 1. Flowchart of Protocol.

System 4 Pro, Biodex Medical Systems, United States), following a protocol adapted from Rossato et al. (2018). All participants remained seated with a trunk flexion of 85°. Only the right limb was securely fixed and assessed. Calibrations were performed according to the manufacturer's recommendations. The range of motion was set at 70°, with full knee extension at 90°. The protocol consisted of: 1) 20 warm-up repetitions at 90°/s; 2) 3 sets of five repetitions at 60°/s in concentric mode for both knee extensors and flexors; 3) 3 sets of five repetitions at 60°/s in eccentric mode for both knee extensors and flexors. The recovery interval between sets and contraction modes was 90 seconds. Peak torque values were recorded for each attempt. The average peak torque values were calculated from the two best attempts and normalize by body mass assessed on a digital scale before the downhill running protocol. To calculate hamstring/quadriceps (H/Q) ratios, the conventional ratio was obtained by dividing concentric flexor peak torque by concentric extensor peak torque, and the functional ratio was calculated by dividing eccentric flexor peak torque by concentric extensor peak torque (Evangelidis et al., 2015).

STEP 4: MAXIMAL AEROBIC VELOCITY TEST

The treadmill running protocol used to determine the maximal aerobic velocity (MAV) was adapted from the study by Dellagrana et al., (2020). Participants began the test at a speed of 6 km/h, and the speed was increased by 0.5 km/h every minute until reaching voluntary exhaustion. The treadmill was set at a 1% incline gradient throughout the entire test. The test was concluded if the participant displayed signs of coordination issues or voluntarily stopped due to fatigue.

STEP 5: DOWNHILL RUNNING PROTOCOL

The downhill running protocol (DRP) was adapted from Baumann et al. (2014). where a speed corresponding to 70% (10.3 ± 1.1 km/h) of the peak aerobic velocity (PAV) obtained from the maximal progressive treadmill test was used (14.7 ± 1.5 km/h). The downhill slope was set at -3°, and participants performed 6 sets of 5 minutes each. The slope adopted considered the technological limitations of the treadmill used. Intervals of 2 minutes between sets were adhered to. The total duration of the DRP was 40 minutes.

STATISTICAL ANALYSIS

All results were presented using descriptive statistics (means and standard deviations). Normality of the data was assessed using the Shapiro-Wilk test, and homogeneity of variances was verified with Levene's test. Reliability and reproducibility between the two measurement time points (-72h and Pre) were assessed using the intraclass correlation coefficient (ICC(2,1) – twoway random, absolute agreement) and the standard error of measurement (SEM = √MSres). ICC values were interpreted as poor (ICC < 0.50), moderate (0.50 ≤ ICC < 0.75), good (0.75 ≤ ICC < 0.90), and excellent (ICC ≥ 0.90). Comparisons across different time points were performed using onesample ttests (for DOMS), One-Way ANOVA for Repeated Measures (for EI, peak torque, and hamstring/quadriceps [H/Q] ratios). Effect sizes were calculated as partial eta squared (η^2p) for ANOVA and Cohen's d for ttests. For ANOVA, effect sizes were interpreted as small ($\eta^2p \geq 0.01$), medium ($\eta^2p \geq 0.06$), and large ($\eta^2p \geq 0.14$). For ttests, Cohen's d was interpreted as small (d ≥ 0.20), medium (d ≥ 0.50), and large (d ≥ 0.80). When significant differences were detected in ANOVA, Tukey's HSD posthoc test was applied. All statistical procedures were performed using SPSS version 27.0 (IBM, Chicago, USA) for Windows.

RESULTS

The echo intensity (EI) values of the Vastus Lateralis (VL) and Rectus Femoris (RF) muscles, as well as the delayed onset muscle soreness (DOMS) values, are presented in Table 1. No significant differences were observed between time points for EI_VL ($F = 0.398$, $p = 0.756$, partial $\eta^2 = 0.024$) and EI_RF ($F = 2.01$, $p = 0.131$, partial $\eta^2 = 0.116$). Regarding reliability (-72h and Pre), the EI_VL presented lower reliability (ICC (2,1) = 0.413; SEM = 3.35. The EI_RF showed moderate testretest reliability (ICC (2,1) = 0.619), with a standard error of measurement (SEM) of 2.99). Regarding DOMS, the one-sample t-test revealed significant increases in VL at 24h ($p = 0.001$, Cohen's $d = 0.92$), 48h ($p = 0.0033$, Cohen's $d = 0.83$), and 72h ($p = 0.0011$, Cohen's $d = 0.95$). For RF, when compared to the -72h and Pré time points, significant increases in DOMS were observed at 24h ($p = 0.002$, Cohen's $d = 0.85$), 48h ($p = 0.002$, Cohen's $d = 0.87$), and 72h ($p = 0.004$, Cohen's $d = 0.80$).

Table 1. Mean values and standard deviations for Echo Intensity (EI) and Delayed Onset Muscle Soreness (DOMS) of the Vastus Lateralis (VL) and Rectus Femoris (RF) muscles at different intervention time periods.

Variables	-72h	Pre	24h	48h	72h
EI-VL (U.A.)	20.5 ± 4.3	19.8 ± 4.9	20.4 ± 5.9	20.1 ± 5.2	19.6 ± 5.2
EI-RF (U.A.)	24.0 ± 4.4	24.6 ± 5.7	23.5 ± 4.3	22.8 ±4.6	23.5 ± 4.8
DOMS_VL (U.A.)	0	0	2.1 ± 1.0*#	2.5 ± 1.1*#	2.6 ± 1.1*#
DOMS_RF (U.A.)	0	0	1.0 ± 1.7*#	1.5 ± 1.7*#	1.4 ± 1.7*#

*Indicates significative difference from -72h; #indicates significative difference from Pre.

Regarding torque parameters, the results are presented in Table 2. A oneway repeatedmeasures Anova revealed a significant effect of time on concentric extensors peak torque ($F = 10.65$, $p < 0.0001$, partial $\eta^2 = 0.399$). Tukey's HSD posthoc test indicated that concentric extensors peak torque was significantly reduced immediately Post and at 24h compared to both baseline time points (−72h and Pre) as well as to 48h and 72h ($p < 0.01$ for all), with no differences between the two baseline measurements or between 48h and 72h ($p > 0.05$). A significant time effect was also observed for concentric flexors peak torque ($F = 6.01$, $p = 0.0011$, partial $\eta^2 = 0.27$). Posthoc analysis showed that concentric flexors peak torque was significantly reduced only immediately Post, when compared to both baseline time points (−72h and Pre) and to 48h and 72h ($p < 0.01$ for all). No significant differences were detected at 24h or between any other time points ($p > 0.05$). For eccentric extensors peak torque, a significant effect of time was found ($F = 6.78$, $p = 0.0008$, partial $\eta^2 = 0.30$). Posthoc comparisons revealed significant reductions immediately Post and at 24h relative to both baseline time points (−72h and pre) and to 72h ($p < 0.05$ for all). Finally, the Anova for eccentric flexors peak torque demonstrated a significant time effect ($F = 12.51$, $p < 0.0001$, partial $\eta^2 = 0.44$). Tukey's test showed that peak torque was significantly reduced immediately Post and at 24h compared to both baseline time points (−72h and pre) and to 48h and 72h ($p < 0.01$ for all). No significant differences were observed between post and 24h or between 48h and 72h ($p > 0.05$).

The conventional and functional H/Q ratio values are presented in Figure 2. For the conventional H/Q ratio (Figure 2a), a significant main effect of time was observed ($F = 3.327$, $p = 0.0245$, partial $\eta^2 = 0.17$). Specifically, a significant increase was noted at 24 hours following the DRP compared to the Pre ($p = 0.043$) and Post ($p = 0.015$) time points. Regarding the functional H/Q ratio (Figure 2b), a significant effect of time was also found ($F = 1.656$, $p = 0.045$, partial $\eta^2 = 0.09$). When compared to the Pre value, a significant reduction was observed only at the Post time point ($p = 0.020$).

DISCUSSION

The aim of this study was to evaluate the effects of a downhill running protocol (DRP, −3°) on muscular quality and delayed onset muscle soreness (DOMS) in the rectus femoris (RF) and vastus lateralis (VL), as well as muscular balance between knee flexors and extensors

Table 2. Mean values and standard deviations of peak torque (PT) for concentric and eccentric contractions of knee extensors and flexors at different intervention time periods.

Variables	-72h	Pre	Post	24h	48h	72h
Concentric extensors peak torque (N.m/kg^{-1})	3.53 ± 0.55	3.43 ± 0 .63	3.10 ± 0.46$^{*\#@\$}$	2.97 ± 0.53$^{*\#@\$}$	3.36 ± 0.66	3.37 ± 0.55
Concentric flexors peak torque (N.m/kg^{-1})	1.77 ± 0.26	1.70 ± 0.24	1.52 ± 0.23$^{*\#@\$}$	1.64 ± 0.24	1.70 ± 0.27	1.73 ± 0.28
Eccentric extensors peak torque (N.m/kg $^{-1}$)	4.15 ± 1.03	4.30 ± 1.08	3.59 ± 0.90$^{*\#\$}$	3,58 ±0.80$^{*\#\$}$	4.00 ± 1.07	4.40 ± 1.09
Eccentric flexors peak torque (N.m/kg^{-1})	2.49 ± 049	2.44 ± 0.46	2.05 ± 0.38$^{*\#@\$}$	2.06 ±0.44$^{*\#@\$}$	2.37 ± 0.48	2.35 ± 0.5

Indicates significative difference: *from -72h; $^{\#}$from Pre; @from 48h; $^{\$}$from 72h.

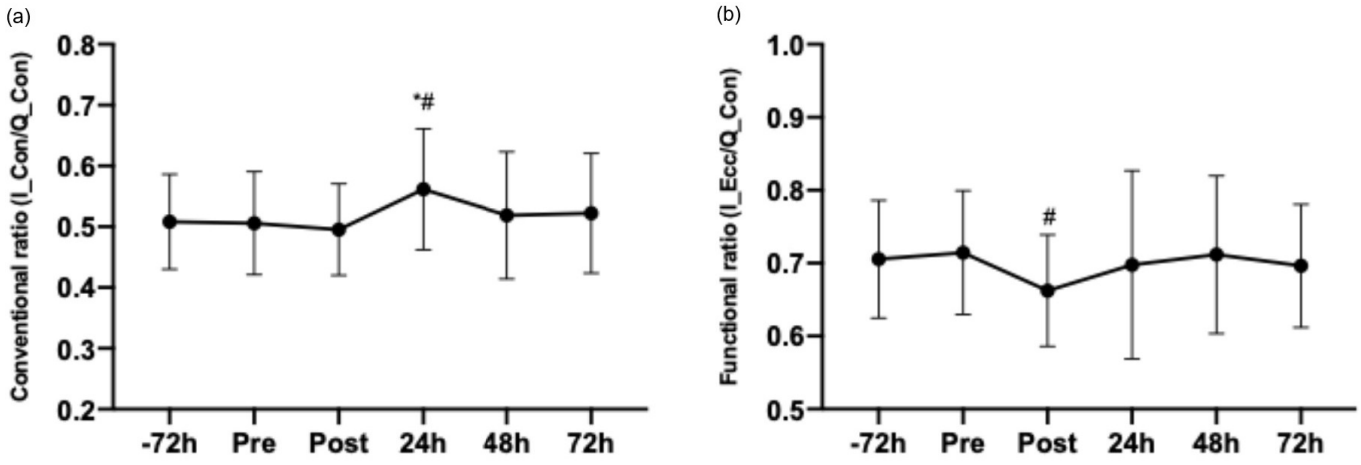

Figure 2. Mean values and standard deviations for (a) conventional ratio and (b) functional ratio. Indicates significative difference: $^{\#}$from Pre; *from Post.

(H/Q ratios). Our hypothesis was that due to downhill running involving predominantly eccentric actions, this would be associated with decreased muscular quality, increased DOMS, and temporary muscular imbalances, thus creating a conducive environment for non-contact injuries. Our results indicated that, although we did not observe significant changes in muscle quality, DRP caused increases in DOMS that remained elevated for 72h, reduction in torque mainly between the knee extensors for up to 24h, and changes in the H/Q ratio for up to 24h after DRP.

Traditionally, Echo Intensity (EI) has been used to assess muscle quality, acute swelling, intramuscular glycogen, and muscle damage (Wong et al., 2020). Concerning muscle damage, several authors have noted that increases in EI (brighter images) indicate damage to connective and muscular tissues, as well as inflammation (Taniguchi et al., 2020). To our knowledge, only Ghyu et al. (2019). evaluated the effects of two downhill running protocols (-9°; 30 minutes; Low intensity = 50% of HRmax and High intensity = 70% HRmax) on quadriceps muscle echo intensity. The authors concluded that compared to low intensity, high intensity led to a significant worsening of quadriceps muscle EI (except Vastus Medialis), lasting up to 48h after downhill running. Our results failed to show significant changes in RF and VL echo-intensity over time. We believe that this is due to the slope used (-3°) which was lower than that used by Ghyu et al. (2019). (-9th). Greater slopes would be associated with greater eccentric overloads and consequent damage to muscle structures (Bontemps et al., 2020).

For DOMS, our data agree with the literature, indicating that downhill running protocols increase the muscle soreness after 24h and 48h (Bontemps et al., 2020). Downhill running involves the participation of eccentric muscle actions compared to flat or uphill running (Bontemps et al., 2020). Eccentric actions, in turn, lead to microdamage in muscle structures, triggering an inflammatory process (Yu et al., 2015). The inflammatory process is characterized by the release of inflammatory mediators (Silva and Macedo, 2011). These mediators act on pain receptors (nociceptors) present in sensory nerve fibers, increasing pain sensitivity (Foschini et al., 2007). Additionally, factors like edema and interstitial pressure lead to increased blood vessel permeability and interstitial pressure, compressing nerve endings and contributing to heightened pain sensation (Cervaens and Barata, 2009). Although we observed significant increases in DOMS after DRP, the reported values were considered low (Reed and van Nostran, 2014), indicating that the characteristics of DRP (40 min; 6 sets of 5 min; intervals of 2 min. between sets and -3° slope), resulted in negligible muscle damage and low DOMS values.

We observed significant reductions in all torque parameters immediately after the DRP (Table 02) compared to -72h and Pre. Except for oncentric flexors peak torque, all the others remained altered to below also after 24 hours and 48h post DRP all parameters returned to normal values. According to Eston et al. (1995) where knee and hip extensors, as well as anterior and posterior muscles of the tibia, tend to be overloaded during downhill running due to their role in decelerating downhill running (anti-gravitational muscles). This would explain the maintenance of the lower values of the extenders, even after 24 hours. Close et al. (2004) compared torque parameters after flat and downhill running (30 minutes, 65% VO_{2max}, -15%). They reported significant reductions in concentric and eccentric PT values of knee extensors immediately after downhill running. Additionally, concentric peak torque values of knee extensors remained below baseline values up to 48h. However, they did not report peak torque of knee flexors. Our results agree with these findings, since after 48h no significant differences were reported in relation to -72h or Pre. Similar with our results, Garnier et al. (2018) evaluated concentric and eccentric peak torque of knee extensors after 45 minutes of downhill running (-15%) at 75% of HR reserve. The results showed the largest reductions in eccentric peak torque (-12.2%) compared to concentric (-10.2%). Our results also indicate greater reductions in eccentric PT after DRP (˜16%) when compared to concentric PT (˜10.6%). However, their analyses were only conducted immediately after downhill running. Therefore, our study was pioneering in evaluating concentric and eccentric peak torque of knee extensors and flexors, before (-72h and Pre) and after the DRP (Post, 24h, 48h, and 72h).

In the present study, the DRP induced changes in H/Q ratios (conventional and functional) (Figures 2a and 2b). While the conventional ratio exhibited increase after 24h, the functional ratio showed reduction, immediately post-DRP. The increase in the conventional ratio after 24h could be explained by a more pronounced reduction in peak torque concentric of knee extensors (-13.4% and – 4.2%) compared to the reduction in peak torque concentric of knee flexors (-3.5% and 7.9%) in pre- and post-DRP values respectively. On the other hand, the reduction in the functional ratio Post DRP compared to Pre, may be associated with a greater reduction in peak torque eccentric of knee flexors (-16%) compared to the peak torque concentric of knee extensors (-9.6%). In review developed by Baroni et al. (2020), it was noted that reference values for both conventional and functional H/Q ratios of knee stabilizing musculature depend on the angular velocity assessed in isokinetic dynamometry. Like present study, Grazioli et al. (2022), and Dellagrana et al. (2015), assessed muscle balance in street runners at 60°/s. Grazioli et al. (2022) reported values of 0.52 ± 0.07 for the conventional H/Q ratio and 0.88 ± 0.12 for the functional ratio, while Dellagrana et al. (2015) reported values of 0.61 ± 0.07 for conventional H/Q ratio. Comparing our finds with those reported by Grazioli et al. (2022) conventional H/Q ratio showed similar results, however for functional H/Q ratio, our values were lower than those observed by Grazioli et al. (2022). These claims suggesting weakness in the knee

flexor muscles during eccentric contractions in our study. Additionally, Assumpção et al. (2014) evaluated the effects of downhill running (30 minutes, 70% vVO_2, -16%) on the H/Q ratio. They assessed isometric strength of knee extensors and flexors Pre, Post, and 48h after downhill running, and concluded that despite a reduction in torque production, the H/Q ratio did not change after downhill running. Therefore, both flexors and extensors exhibited a similar decrease in strength, preserving the H/Q ratio.

Our study has strengths and limitations. Among the strengths, the materials and methods used stand out (duration of assessments, peak torque parameters evaluated, and imaging diagnosis). Among the limitations, we can highlight the participants conditioning, and lack of a comparison with flat or uphill running protocol. The participants, although physically active, were not runners. This could be a limitation for extrapolating the results. However, it is known that increasingly street running supporters are individuals who chooses for the activity without the guidance of a physical education professional and without proper physical preparation. Finally, future research could benefit from the inclusion of a control group (i.e., flat or uphill protocols).

CONCLUSION

The DRP was not effective in reducing muscular quality in the VL and RF but increasing DOMS in the VL and RF up to 72h. DRP was able to reduce all peak torque parameters immediately after, and for the knee extensors, the reduction remained for up to 24 hours. This reduction affected the 24h H/Q conventional ratio (large effect) and the H/Q functional ratio (medium effect) post DRP. Therefore, athletes and coaches should pay special attention to recovery post and 24 hours after downhill running, as the environment appears to be conducive to non-contact injuries.

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CONFLICTS OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

DATA AVAILABILITY

The data will be made available when requested.

AUTHORS' CONTRIBUTION

Esmeralda Lhia do Nascimento Santos participated in the conceptualization, data collection, methodology, and writing and review of the article. Raisa Seabra participated in the methodology, writing and review of the article. Rodolfo André Dellagrana participated in the writing and review of the article. João Otacílio Libardoni dos Santos participated in the conceptualization, statistical analysis, writing and review. Mateus Rossato participated in the conceptualization, supervision, writing and review of the article.

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