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Effect of muscle fatigue and physical activity level in motor control of the gait of young adults

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ABSTRACT

The aim of this study was to analyze the effect of muscle fatigue in active and inactive young adults on the kinematic and kinetic parameters of normal gait and obstacle crossing. Twenty male subjects were divided into active (10) and inactive (10), based on self-reported physical activity. Participants performed three trials of two tasks (normal gait and obstacle crossing) before and after a fatigue protocol, consisting of repeated sit-to-stand transfers until the instructed pace could no longer be maintained. MANOVAs were used to compare dependent variables with the following factors: physical activity level, fatigue and task. The endurance time in the fatigue protocol was lower for the inactive group. Changes of gait parameters with fatigue, among which increased step width and increased stride speed were the most consistent, were independent of task and physical activity level. These findings indicate that the kinematic and kinetic parameters of gait are affected by muscle fatigue irrespective of the physical activity level of the subjects and type of gait. Inactive individuals used a slightly different strategy than active individuals when crossing an obstacle, independently of muscle fatigue.

1. Introduction

Fatigue affects the performance of daily activities, such as walking. To maintain motor performance in the presence of fatigue, adjustments in temporal and spatial parameters of gait are required [1–3]. Fatigue effects are task-dependent [4,5] and may thus be different for gait in environments of different complexity. While fatigue effects on gait characteristics have been studied to some extent in an unobstructed environment allowing free gait, characteristics of adaptive gait for example to cross or circumvent obstacles, as is commonly required in daily locomotion [6], has to the best of our knowledge not been studied previously.

Gait characteristics appear to be influenced by physical activity levels, with inactive individuals showing differences from active individuals in free gait reflective of a poor neuromuscular condition affecting both balance control and propulsion [9,16]. In adaptive gait, inactive individuals showed a lower walking speed and increased foot-obstacle horizontal distance of the leading limb compared to active individuals [8]. Physical activity levels also mediate fatigue development [9], with inactive individuals being more fatigable than active individuals [10], and may alter fatigue effects on motor performance.

The aim of this study, therefore, was to analyze the effects of muscle fatigue in active and inactive young adults on the kinematic and kinetic parameters of free and adaptive gait. We expected that the motor control of free and adaptive gait would be dependent on the physical activity level before and after fatigue induction and hypothesized interaction effects between physical activity level and fatigue. Furthermore, we expected that muscular fatigue affect free and adaptive gait differently. We analyzed spatial–temporal gait characteristics, which have been related to fall risk or have been shown adapted to decrease fall risk (e.g. gait speed, step duration, step width). In addition, we looked at the spatial relations between the feet and the obstacle, which determine the probability of tripping over or stepping on the obstacle. Finally, we analyzed vertical ground reaction forces to characterize weight acceptance and horizontal forces to provide insight into how speed is modulated.

2. Material and methods

2.1. Participants

Twenty young male adult participants of this study were classified into active and inactive (Table 1). The exclusion criteria

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Table 1

Mean and standard deviation of the general characteristics, anthropometric measure, scores on the multidimensional fatigue inventory and habitual physical activity, maximal isometric force before (pre) and after (post) induction to fatigue and endurance time to fatigue for each group. (*) pre ($\neq$) post; (+) active group $\neq$ inactive group.

		Group	
		Active	Inactive
Age (months)		296.5 ± 34.2	296.9 ± 35.4
Weight (kg)		73.2 ± 4.4	82.7 ± 17.6
Height (cm)		178.7 ± 10.1	178.8 ± 5.6
Percentage of body fat		9.6 ± 4.1^{+}	20.1 ± 8.9
Multidimensional fatigue inventory (points)		47.5 ± 5.6	46.9 ± 10.3
Habitual Physical Activity (points)		10.4 ± 1.49^{+}	5.9 ± 1.2
Maximal isometric force (N)	(pre)	3346.7 ± 1002.3*	3099.1 ± 1351.9*
	(post)	2923.2 ± 1132.4	2730.8 ± 1302.1
Endurance time to fatigue (s)		1018.4 ± 697.4+	416.4 ± 381.7

of the study were factors that could interfere with gait and other experimental procedures, such as medication use, presence of osteomyoarticular, neuromuscular or cardio-respiratory diseases and balance and vision disorders. During the sample selection process, 10 initially recruited subjects did not fit the criteria of the study. The study was approved by the local Ethics Committee (2055/2008).

The active group was composed of individuals who performed physical activity for more than three months for at least three times a week and at least 1 h/day and the inactive group was composed of individuals who had not performed regular physical activity in at least the last 3 months [11,12]. In addition, participants filled out the questionnaire of habitual physical activity [13]. In this questionnaire the responses are scored on a five-point scale and result in three different indices reflecting physical activity during work, leisure time excluding sport and sport activities. The summation of the three indices was defined as the overall physical activity index. The values for the active group were ≥9 and the inactive group scored ≤7 [14].

2.2. Experimental design

Participants were instructed not to perform any strenuous physical activity 48 h before evaluation. The experiment was divided into 2 days. On the first day, participants filled out a questionnaire on medical history, the questionnaire of habitual physical activity and the multidimensional fatigue inventory [15]. The latter was used to determine the presence of fatigue prior to study, and no fatigue was found in either of the groups (Table 1). In addition, the anthropometric measurements were performed.

At the beginning of the second day, there was warm-up period of 5 min, with walking, stretching and movements in the leg press. After that, participants performed the trials of free and adaptive gait following the maximum voluntary isometric contractions. Immediately after the he maximum voluntary isometric contractions, the fatigue protocol was performed. Subsequently, the gait tests and the maximal voluntary contractions were performed once again.

2.3. Gait task

Three trials for each experimental condition, free and adaptive gait, with the order randomly defined were performed before and after the fatigue protocol. The starting point of each gait trial was adjusted to ensure that the obstacle was crossed with the right leg and that at least two strides were completed prior to obstacle crossing. The instruction given to the participant was to walk over an 8 m pathway, at self-selected speed. For the adaptive gait trials, the participant was instructed to avoid contact with the obstacle (15 cm high, 80 cm wide and 2 cm thick), which was positioned between two force platforms. For free gait we analyzed the stride (period between two consecutives heel contacts of the left limb) in the middle of the pathway, which was compared to the stride preceding the obstacle crossing for adaptive gait (approach phase). For adaptive gait, we additionally analyzed the crossing step (from heel contact of the left limb in front of the obstacle to heel contact of right limb behind the obstacle) and the step (from heel contact of the right limb behind the obstacle to heel contact of left limb behind the obstacle) after crossing the obstacle ($N + 1$).

2.4. Data collection

Ground reaction forces were measured using two force plates (AccuGait, Advanced Mechanical Technologies) at a sample rate of 200 samples/s, positioned across the central area of the pathway (20 cm away from each other). Acquisition of kinematic gait parameters was accomplished with a three-dimensional optoelectronic system (OPTOTRAK Certus), positioned in the sagittal right plane, using a sample rate of 100 samples/s. Four infrared emitters were placed over the following anatomical points: lateral face of calcaneus and head of the fifth metatarsus of the right limb, and medial face of calcaneus and head of the first metatarsus of the left limb. To determine the heel contact and toe-off of the limbs during gait, only the markers on the calcaneus and toe were used [16]. The data acquisition systems were electronically synchronized.

2.5. Isometric force measurements

After the free and adaptive gait trials, maximum voluntary isometric contractions were performed in a leg press device [17]. A load cell with precision of 0.98 N was used in combination with a signal amplifier (EMG System do Brasil Ltd.). The participant performed the test with both legs, with the instruction to produce maximum force as fast as possible. Total contraction duration was 5 s. The participants were seated in a backward inclined chair, with the hip joint at 90° (180° is full extension) and knee joint at 110° (180° is full extension). Participants performed two attempts before and after the fatigue protocol, with 2 min rest between attempts. The means of the two attempts before and after muscle fatigue were calculated for each participant.

2.6. Fatigue protocol

To induce fatigue, the participant performed the sit-to-stand task, with arms across the chest region from a chair [1], with the speed controlled by a metronome (30 beats/min). So, the cycle of sitting to standing and back to sitting was performed in 2 s. A standard chair (43 cm in height, 41 cm in width, 42 cm in depth) without arm rests was used for all participants. The instruction given to the participants was: stand up to an upright position with your knees fully extended, then sit back down and repeat this at the beat of the metronome until you can no longer perform the task.

The fatigue protocol was stopped and it was assumed that the leg muscles were fatigued when the subject indicated not to be able to continue the task, or when the subject no longer performed at the desired movement frequency, or after 30 min. The time between the fatigue protocol and the gait trials (<3 min) was expected not to allow full recovery [3].

2.7. Data analysis

All the data were digitally filtered using zero-lag Butterworth filters. Kinematic data were filtered with a 5th order low-pass filter with cutoff frequency of 6 Hz. Kinetic data were filtered with 4th order filter with cutoff frequency of 16 Hz, and the magnitude of the ground reaction force was normalized by body weight. For free and adaptive gait (approach phase), the stride length, step width, stride duration, single and double support duration, speed in the stride (stride length divided by stride duration), maximum braking and propulsive vertical and anterior–posterior forces, and braking latency time (time between the foot contact with the ground and the maximum braking force) of the vertical forces were measured. For adaptive gait trials, step length, step width, step duration, single and double support duration and speed for the obstacle crossing and $N+1$ steps, the foot-obstacle distance before and after obstacle crossing, and toe-clearance for the leading and trailing limbs were calculated. Moreover, the maximum force in the maximum voluntary contractions and the endurance time in the fatigue protocol were measured.

Table 2
Mean and standard deviation of the free and adaptive gait variables. Kinematics variable of approach phase and kinetic variables. BW: body weight; (#) free gait ≠ adaptive gait.

	Free gait	Adaptive gait
Stride length (cm)	135.91 ± 11.74$^{\#}$	131.30 ± 10.50
Step width (cm)	12.10 ± 2.70	12.57 ± 2.91
Single support duration (s)	0.77 ± 0.05$^{\#}$	0.75 ± 0.07
Double support duration (s)	0.29 ± 0.4$^{\#}$	0.35 ± 0.04
Stride duration (s)	1.07 ± 0.08$^{\#}$	1.11 ± 0.10
Stride speed (cm/s)	127.21 ± 17.17$^{\#}$	119.22 ± 14.27
Maximum braking vertical force (BW)	1.08 ± 0.07$^{\#}$	1.20 ± 0.08
Maximum propulsive vertical force (BW)	1.11 ± 0.05$^{\#}$	1.17 ± 0.05
Braking latency time of vertical force (ms)	0.18 ± 0.02$^{\#}$	0.16 ± 0.02
Maximum braking anterior–posterior force (BW)	0.15 ± 0.03$^{\#}$	0.20 ± 0.04
Maximum propulsive anterior–posterior force(BW)	0.19 ± 0.03$^{\#}$	0.24 ± 0.04

Table 3
Mean and standard deviation of spatial and temporal parameters according fatigue (independently task and physical activity level) and physical activity level (independently task and fatigue). Kinematic variables of approach phase, crossing obstacle (N) and step after crossing ($N+1$). LL: leading limb; TL: trailing limb. * pre (before fatigue) ≠ post (after fatigue).

		Pre	Post	Active	Inactive
Stride/step length (cm)	Approach phase	135.66 ± 11.71	130.82 ± 10.57	132.65 ± 8.72	134.55 ± 13.77
	N	71.67 ± 8.01	72.79 ± 7.17	73.55 ± 7.28	70.94 ± 8.49
	$N+1$	65.22 ± 6.27	66.52 ± 7.08	63.70 ± 7.48	68.04 ± 6.63
Step width (cm)	Approach phase	11.48 ± 2.51*	11.80 ± 2.70	11.97 ± 3.09	12.70 ± 2.94
	N	10.58 ± 2.67*	12.80 ± 3.06	11.96 ± 3.18	11.41 ± 4.08
	$N+1$	14.22 ± 4.36*	16.11 ± 6.02	14.32 ± 5.47	16.01 ± 5.46
Single support duration (s)	Approach phase	0.78 ± 0.06*	0.76 ± 0.07	0.78 ± 0.04	0.74 ± 0.07
	N	0.42 ± 0.05	0.42 ± 0.06	0.43 ± 0.04	0.40 ± 0.06
	$N+1$	0.50 ± 0.06	0.50 ± 0.06	0.50 ± 0.05	0.50 ± 0.08
Double support duration (s)	Approach phase	0.30 ± 0.04	0.35 ± 0.04	0.32 ± 0.04	0.32 ± 0.06
	N	0.20 ± 0.04*	0.18 ± 0.04	0.19 ± 0.04	0.20 ± 0.06
	$N+1$	0.16 ± 0.02*	0.15 ± 0.02	0.16 ± 0.02	0.15 ± 0.03
Stride/step duration (s)	Approach phase	1.08 ± 0.09*	1.12 ± 0.10	1.11 ± 0.08	1.07 ± 0.11
	N	0.62 ± 0.09	0.61 ± 0.07	0.63 ± 0.07	0.60 ± 0.11
	$N+1$	0.67 ± 0.07*	0.65 ± 0.07	0.66 ± 0.07	0.66 ± 0.09
Stride/step speed (cm/s)	Approach phase	121.60 ± 15.81*	124.83 ± 16.62	119.49 ± 11.96	126.93 ± 19.58
	N	117.66 ± 28.37*	124.66 ± 36.33	117.14 ± 19.24	125.18 ± 28.18
	$N+1$	98.88 ± 15.62*	103.80 ± 18.62	96.91 ± 18.23	106.43 ± 18.26
Foot-obstacle distance before obstacle – LL (cm)	N	112.66 ± 10.13	113.96 ± 9.75	112.43 ± 8.88	113.98 ± 13.00
Toe-clearance – LL (cm)	N	9.09 ± 3.01	9.38 ± 2.91	8.36 ± 2.40	10.06 ± 3.78
Foot-obstacle distance after obstacle – LL (cm)	N	24.22 ± 4.78	24.42 ± 5.24	24.91 ± 6.30	23.73 ± 6.15
Foot-obstacle distance before obstacle – TL (cm)	N	48.18 ± 6.19	48.41 ± 6.36	49.68 ± 6.45	46.77 ± 8.08
Toe-clearance – TL (cm)	N	31.28 ± 3.64	30.16 ± 4.59	29.65 ± 5.85	31.65 ± 4.67
Foot-obstacle distance after obstacle – TL (cm)	N	89.62 ± 8.64	91.05 ± 10.37	88.81 ± 11.29	91.78 ± 10.19

2.8. Statistical analysis

The dependent variables of interest were statistically analyzed with SPSS 15.0 for Windows® ($\alpha < 0.05$). The data were normally distributed, verified by the Shapiro–Wilk test. To verify the similarity between groups, the anthropometric characteristics, age, Multidimensional Fatigue Inventory values, maximum force and kinematic and kinetic variables before fatigue induction were compared through the Student t test for independent groups. The same statistical test was used to compare the endurance times between groups. To verify the development of fatigue, the Student t test for paired samples was applied on the maximum force values before and after the fatigue protocol for each group. The dependent variables of free and adaptive gait were compared using MANOVAs. One MANOVA was used for kinematic data of free gait and the approach phase of adaptive gait, with as independent variables level of physical activity (active and inactive), fatigue (before and after) and task (free and adaptive gait), with repeated measures over the last two factors. A similar MANOVA was used for kinetic data of the first force platform. The third MANOVA was for the kinetic data of the second force plate in adaptive gait and had level of physical activity and fatigue as independent variables, with repeated measures over fatigue. Similarly two MANOVAs were performed for kinematics of obstacle crossing and step $N + 1$. When MANOVA revealed a main effect, univariate analyses were used to locate the differences.

3. Results

The active and inactive groups were similar for age, anthropometric characteristics, muscle strength, fatigue level (Table 1) and different only with respect to body fat percentage ($t_{1,8} = -3.3$, $p < 0.01$). The fatigue protocol did induce fatigue in both groups as demonstrated by the lower maximum voluntary forces (active individuals: $t_{1,9} = 4.1$, $p < 0.01$; inactive individuals: $t_{1,9} = 2.6$, $p < 0.01$). Among the active participants, four individuals performed for the full 30 min; among the inactive participants none completed the full 30 min. Mean endurance time was shorter in the inactive individuals (Table 1; $t_{1,8} = 2.4$, $p < 0.02$).

Before fatigue, the groups were similar for all gait variables. Analysis of the kinematics of free gait and the approach phase in adaptive gait revealed main effects of task (Wilks' Lambda = 0.58, $F_{7,12} = 27.70$, $p < 0.01$) and fatigue (Wilks' Lambda = 0.33, $F_{7,12} = 3.40$, $p < 0.03$) only.

For task (Table 2), univariate analyses indicated that free gait coincided with shorter stride durations ($F_{1,18} = 9.95$, $p < 0.01$) and double support duration ($F_{1,18} = 107.08$, $p < 0.01$), larger stride length ($F_{1,18} = 23.58$, $p < 0.01$), higher speed ($F_{1,18} = 23.56$, $p < 0.01$) and longer single support duration ($F_{1,18} = 5.83$, $p < 0.02$). With respect to fatigue (Table 3), univariate analyses showed that fatigue coincided with increased step width ($F_{1,18} = 18.11$, $p < 0.01$) and speed ($F_{1,18} = 10.09$, $p < 0.01$), and decreased single support ($F_{1,18} = 6.58$, $p < 0.01$) and stride durations ($F_{1,18} = 10.89$, $p < 0.01$).

For the kinetic data of free gait and adaptive gait, the MANOVA indicated an effect of task (Wilks' Lambda = 0.09, $F_{7,12} = 16.114$, $p < 0.01$) and fatigue (Wilks' Lambda = 0.29, $F_{7,12} = 4.17$, $p < 0.01$). Specifically for task (Table 2), the univariate analyses showed that adaptive gait coincided with greater maximum braking and propulsive vertical forces ($F_{1,18} = 114.70$, $p < 0.01$ and $F_{1,18} = 22.07$, $p < 0.01$) as well as greater maximum braking and propulsive anterior–posterior forces ($F_{1,18} = 89.31$, $p < 0.01$ and $F_{1,18} = 24.29$, $p < 0.01$). For fatigue (Table 4), the analysis indicated that fatigue coincided with a lower vertical maximum braking force ($F_{1,18} = 5.55$, $p < 0.03$).

Concerning obstacle crossing and $N + 1$ variables (Table 3), the MANOVAs showed an effect of fatigue (Wilks' Lambda = 0.14, $F_{10,9} = 5.38$ $p < 0{,}01$ and Wilks' Lambda = 0.31, $F_{6,13} = 4.64$, $p < 0{,}01$). For obstacle crossing and $N + 1$, univariate analyses revealed that fatigue coincided with a larger step width ($F_{1,18} = 6.37$, $p < 0.01$ and $F_{1,18} = 27.33$, $p < 0.01$), shorter double support time ($F_{1,18} = 7.51$, $p < 0.01$ and $F_{1,18} = 16.33$, $p < 0.01$), and higher speed ($F_{1,18} = 5.35$, $p < 0.03$ and $F_{1,18} = 8.34$, $p < 0.01$). In addition, for $N + 1$ only we found a shorter step duration ($F_{1,18} = 6.55$, $p < 0.02$) after fatigue.

In the kinetic data of the force platform after the obstacle (Table 4), the MANOVAs showed an effect of physical activity level (Wilks' Lambda = 0.35, $F_{7,12} = 3.09$ $p < 0{,}04$). The univariate analyses showed that inactive individuals produced a higher maximum braking anterior–posterior force ($F_{1,18} = 7.1$, $p < 0.01$) and maximum propulsive vertical force ($F_{1,18} = 6.42$, $p < 0.02$).

4. Discussion

The aim of this study was to analyze the effect of muscle fatigue in active and inactive young adults on the kinematic and kinetic parameters of free and adaptive gait. The expectations of the study were confirmed in part, by showing that muscle fatigue interferes with spatial–temporal and kinetic parameters of free and adaptive gait, but fatigue effects were not different between active and inactive individuals. Active young adults showed greater endurance in the fatigue induction protocol than inactive young adults. Furthermore, the changes in the spatial–temporal gait parameters with fatigue were independent of the type of gait.

The adjustments in adaptive gait compared to free gait consisted of increased stride and double support durations and decreased stride length, single support duration and stride speed. This speed modulation appears to be caused by a larger magnitude of the negative horizontal (braking) force in the last stride before crossing the obstacle. Locomotion in complex environments requires adaptive ability from the locomotor system [7] and more attention [18], especially when crossing an obstacle [19,20]. Reduced speed allows more exploration and collection of relevant information and more time for planning the action [21]. The decreased step length, stride speed and stride duration appear to disclose the use of such proactive mechanisms for modulation of the effector system according to the perceived environmental characteristics [22] and an anticipatory strategy to guarantee dynamic stability during obstacle crossing [23]. From this

Table 4

Mean and standard deviation of kinetic parameters according fatigue (independently task and physical activity level) and physical activity level (independently task and fatigue). Kinetic variables of approach phase and crossing obstacle (*N*). (*) pre (before fatigue) ≠ post (after fatigue); (+) active group ≠ inactive group.

		Pre	Post	Active	Inactive
Maximum braking vertical force (BW)	Approach phase	1.15 ± 0.09*	1.12 ± 0.10	1.13 ± 0.10	1.14 ± 0.10
	N	1.15 ± 0.11	1.12 ± 0.08	1.11 ± 0.09	1.16 ± 0.11
Maximum propulsive vertical force (BW)	Approach phase	1.15 ± 0.06	1.14 ± 0.06	1.13 ± 0.06	1.16 ± 0.07
	N	1.10 ± 0.06	1.10 ± 0.07	1.07 ± 0.07+	1.13 ± 0.12
Braking latency time of vertical force (ms)	Approach phase	0.17 ± 0.02	0.17 ± 0.03	0.17 ± 0.02	0.17 ± 0.03
	N	0.17 ± 0.03	0.16 ± 0.04	0.17 ± 0.03	0.17 ± 0.04
Maximum braking anterior–posterior force (BW)	Approach phase	−0.18 ± 0.04	−0.17 ± 0.04	−0.16 ± 0.04	−0.19 ± 0.04
	N	−0.26 ± 0.09	−0.25 ± 0.09	−0.22 ± 0.03+	−0.26 ± 0.02
Maximum propulsive anterior–posterior force (BW)	Approach phase	0.22 ± 0.04	0.21 ± 0.04	0.20 ± 0.04	0.23 ± 0.04
	N	0.13 ± 0.10	0.15 ± 0.10	0.12 ± 0.03	0.14 ± 0.03

perspective, we expected more pronounced changes with fatigue in adaptive gait than in free gait, which were, however, not observed.

The fatigue protocol used can be expected to mainly affect the quadriceps muscles. Indeed, knee extension strength was reduced after the fatigue protocol. Reduced strength after exercise is considered the indication of muscle fatigue in accordance with its definition as a loss of force generating capacity [9,24]. The decrease of the maximum vertical force in the braking phase in both tasks may be a consequence of this loss of force producing capacity, through decreased knee stiffness during weight acceptance. Moreover, in the approach phase of stepping down, we found that quadriceps muscle fatigue coincided with a decreased muscle activity of the quadriceps muscle [25]. Quadriceps fatigue adversely affects knee proprioception [26] and postural control in single leg stance [27], and has been associated with an increased risk of falling [2,3]. Modulations in performance with fatigue were not task-dependent. One possible explanation is that, despite that individuals did need to adjust their gait when the obstacle was present, this task is not very challenging for young adults. Possibly fatigue of another muscular group or a more challenging adaptive task could show different results.

The participants in this study appeared to seek more stability during gait after the fatigue protocol than before. They increased step widths in both free and adaptive gait as was previously demonstrated in elderly adults in free gait [1]. Increased step width provides a larger margin of safety in controlling medio-lateral movements of the body's center of mass [28]. Participants also reduced stride durations and related variables, such as durations of single and double support irrespective of the type of task. Reduced step duration, facilitates control of the body center of mass in the medio-lateral and fore-aft direction [28,29] and appears to be the preferred strategy to deal with balance threats [30] even if this coincides with an increased speed [4], as was the case in the present study. In line with the present results, increased gait speed with fatigue was found in older people [31]. This may be a direct consequence of the reduction in step duration. On the other hand participants may have tried to perform the task as quickly as possible [31] and the increase in speed could be a risky strategy that decreases the reaction and processing time available to plan crossing the obstacle [19–21], which may be compensated for by larger step width [32]. Previous authors have suggested that muscle fatigue increases fall risk [2,3], however this was based on an increased heel contact velocity, which mainly relates to the risk of slipping. In the present study, we did not find a decrease in braking latency time, which would indicate a less safe weight transfer to the new stance leg. Furthermore, toe-clearance, the most obvious indicator of the risk of tripping in the adaptive gait task, did not change with fatigue in either leg.

Active and inactive young adults showed almost the same behavior before and after muscle fatigue. The active group appeared to have a better muscular capacity, as reflected by the longer endurance times. However, muscle strength before and after fatigue were not different between groups. A similar general locomotor strategy for active and inactive young adults was previously found in free gait and adaptive gait [8]. However, gait speed and speed of the leading leg in crossing an obstacle were higher in the active participants [8]. In the present study, the only difference between groups was found also for the leading leg in the crossing step, where inactive individuals produced a higher maximum braking anterior–posterior force. This suggests a somewhat more cautious strategy, reducing gait speed even further after the first step over the obstacle, to facilitate crossing of the trailing limb. The subsequent maximum propulsive vertical force was higher and there was tendency towards a similar effect in the horizontal force, probably to increase gait speed again after the obstacle is crossed.

Some limitations of this study are evident. The use of a standard chair for all participants may induce early fatigue in taller individuals. The fixed height of the obstacle can similarly have increased between-subject variance, in this case affecting smaller individuals. However, in everyday motor tasks, individuals of different stature use the same chairs and cross-similar height obstacles, with 15 cm being comparable to the standard curb height. Furthermore, the groups had similar height, body weight and gait variables before fatigue, avoiding a possible interference of these limitations in the results. Finally, we used a relatively small sample of participants (ten young adults in each group). Considering these limitations, generalization of especially negative results should be done with care.

In the present study, kinematic and kinetic parameters of gait were affected by muscle fatigue irrespective of the physical activity level of the subjects. For free and adaptive gait, muscle fatigue did not have task-dependent effects. Inactive individuals used a slightly different strategy than active individuals when crossing an obstacle, independently of muscle fatigue.

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Conflict of interest statement

The authors have no conflicts of interest to disclose. All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) our work and manuscript. All authors have approved the final article.

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