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ORIGINAL RESEARCH

Strategies adopted by younger and older adults while operating a non-pedal tricycle

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Abstract
Background: Exercises that could prevent gait impairment of older adults should be implemented in such a way that practitioners can keep motivation and adherence independent of older adults fitness levels.
Objective: This study describes how younger and older adults use a non-pedal tricycle to transport their bodies along a pathway.
Methods: Nine younger (24 ± 4.9 y) and nine older (66 ± 4.0 y) adults participated in this study. They moved along a straight pathway at a self-selected comfortable speed with reflective markers on their main lower limb landmarks. A computerized gait analysis system with infrared cameras was used to obtain kinematic data to calculate spatial-temporal parameters and lower limb angles.
Results: Overall, participants from both groups were able to perform the task moving at a similar mean speed, with similar stride length and ankle joint excursion. Older adults had higher cadence (mean difference of 17 steps/min; 95% CI = 0.99–1.15) and hip excursion (mean difference of 12°; 95% CI = 28–33), longer stance duration (mean difference of 3.4%; 95% CI = 56.2–59.5), and lower knee excursion (mean difference of 6°; 95% CI = 47.9–53.8) than younger adults.
Conclusion: Older adults were able to transport their body with a non-pedal tricycle with more hip and less knee excursion than younger adults. Professionals that work with the older population should look at and take into consideration the use of non-pedal tricycles in exercise protocols and investigate the long-term impacts.

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Introduction

According to the World Health Organization,[1] the world population of people more than 60 years of age will reach more than two billion people in the next 43 years. Data from the Instituto Brasileiro de Geografia e Estatística – IBGE[2] revealed that in 2013, there were more than 23 million people over 60 years of age, constituting 13% of the Brazilian population. This institute indicated that by 2020, the elderly population in Brazil will be more than 30 million and the number of people over 80 years old will increase 14%.[2] Because life expectancy will continue to increase, it is imperative to provide older adults with opportunities to maintain independence and improve quality of life for as long as possible.

Older adults might be more fragile and functionally dependent in physical domains. Consequently, they may have difficulty performing daily activities, which decreases their autonomy.[3] Exercise is one of the best ways to reduce morbidity throughout the life span and to maintain independence.[4] Different interventions have been used in older adults, such as stretching, dancing, localized gymnastics, and yoga.[5]

It is important to select appropriate exercises that best fit the needs of the older population. It is also important to use devices that allow intervention protocols that practitioners can use to sustain motivation and adherence, considering that older adults might have different fitness levels. In this study, the authors considered the use of a non-pedal tricycle, a new device based on an equipment that has been used mainly in Europe, known as ''PETRA RaceRunning'' tricycle[6] (Fig. 1). This device contains one front and two back wheels, a saddle, a trunk support that the users can lean their trunk on anteriorly, and an open rear frame that permits lower limb movements in different modes. There is no pedaling system and the propulsion is through foot contact with the ground. The tricycle has been used as a means of locomotion, and for health-related exercise and balance training.

Figure 1 Illustration of the non-pedal tricycle adapted for the study. *Note*: The arrows indicate the adaptation made to enable adjustments to the front and back wheels in order to have the non-pedal tricycle either higher or lower depending on the height of the user.

Although the non-pedal tricycle has been employed among individuals with different gait impairments and in different settings,[6] there is a lack of information regarding the method individuals use to transport their body from one point to another using this equipment. Considering that the non-pedal tricycle could be employed for an exercise protocol for the older population, the aim of this study was to describe how younger and older adults use a non-pedal tricycle to transport their bodies along a pathway.

Methods

Sample

Nine younger and nine older adults, conveniently sampled, participated in this cross-sectional study. The authors excluded participants with any known musculoskeletal injuries or neurological disorders, anyone taller than 1.8 m, with body mass index greater than 35 kg/m^2, and who had undergone any surgical procedure that could influence their movement. The younger adults were either undergraduate or graduate students recruited from the university where the study took place. Older adults were recruited from the local community, through personal contact. Mean measurements of participants ($\pm$SD) for younger and older participants, respectively, were: age of 24 ($\pm$4.9) and 66 ($\pm$4.0) years, height of 1.65 ($\pm$0.09) and 1.60 ($\pm$0.05) meters, body mass of 61.9 ($\pm$7.7) and 61.0 ($\pm$12.2) kg, and body mass index of 22.7 ($\pm$2.2) and 23.9 ($\pm$4.4) kg/m^2. None of the participants had previous experience with the device or experimental procedures and all of them reported that they were healthy and free of any known disorder.

The Institutional Ethics Committee of Universidade Cruzeiro do Sul, São Paulo, SP, Brazil approved the study protocol (#182/2014). In addition, all procedures were performed with the adequate understanding and written consent of all participants.

Experimental procedures

The device used in this study was a non-pedal tricycle (Fig. 1) that was manufactured based on the measurements for a middle size ''PETRA RaceRunning'' tricycle.[6] The authors made one adaptation to the new device to enable adjustments to the front and back wheels in order to make the non-pedal tricycle either higher or lower depending on the height of the user.

Reflective markers were placed on each subject on the sacrum, bilaterally on the superior iliac crest, the midpoint of the lateral femur, the lateral knee joint axis, the midpoint of the lateral tibia, the lateral malleolus, the calcaneus, and the second metatarsal head, based on the Vicon Plug-in Gait model,[7] to define the pelvis, thigh, shank, and foot segments. A computerized gait analysis system (VICON Bonita 10) with seven infrared cameras recorded kinematic data. A calibration trial was conducted prior to testing wherein each participant stood upright to record the neutral position (baseline) of lower body segments and joints.

Before data acquisition, the saddle and the wheels were adjusted according to the height of the participant to accommodate the participant comfortably on the non-pedal tricycle. All participants practiced for a few trials until they felt comfortable using the device in the experimental situation. The authors instructed participants to move barefoot at a comfortable and self-selected speed for approximately 10 m using the non-pedal tricycle. At the end of the pathway, they turned around and repeated the task back to the initial position. Each participant performed approximately 10 trials to and from the 10 m end of the pathway.

Data analysis

Two consecutive and steady state strides per trial by each participant were analyzed, for a total of three trials. The trial selection was determined by the best visualization of the reflective markers as the participants moved with no interruption. A stride (gait cycle) was defined as two consecutive foot contacts with the ground of the same limb along the progression line. In addition to the foot contacts, toe-off events during a stride were identified for subsequent calculation of the spatial-temporal organization of the stride.[8]

Pelvis, hip, knee, and ankle joint angles were processed with Vicon Nexus software and subsequent analyses were performed using a customized routine developed in Matlab (MathWorks, Inc.). For each of the calculated angles, strides were normalized in time from 0% to 100% with 1% step. These cycles were compared to the neutral angles measured during the calibration trial and were averaged to obtain the mean for each participant. The same procedure was repeated to obtain the mean cycle among participants.

The outcomes analyzed in this study were: mean gait speed, cadence, stride length, stance duration, joint range of motion for hip, knee, and ankle, minimum angles of the hip (extension) and ankle (plantar flexion), and maximum angles of the knee (flexion) and ankle (dorsiflexion) during each stride in the sagittal plane. Mean gait speed was calculated as the rate of the distance traveled over duration (determined by the position of the sacrum marker). Stride length was calculated as the distance between two consecutive contacts of the same foot to the ground along the progression line (determined by the position of the heel marker). Stance duration was determined by the time interval the foot was in contact with the ground.[8] Joint range of motion was calculated as the difference between maximum and minimum joint excursions. Data from right and left sides were averaged before any comparison between groups.

Statistical analysis

For all outcome measures, data from the three trials were averaged for each participant. Univariate analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) were employed, using respective group (younger and older adults) as the factor. The dependent variables for the ANOVA were mean gait speed, cadence, stride length, stance duration, maximum extension of the hip, and maximum flexion of the knee. The dependent variables for the MANOVA were joint range of motion of the hip, knee, and ankle, ankle maximum dorsiflexion, and maximum plantar flexion. Univariate analyses were employed as necessary. Between-group effect sizes were calculated as the difference in mean values from each group divided by the pooled standard deviation. Effect sizes were defined using Cohen *d* classifications ($d = 0.2$, small; $d = 0.5$, medium; $d = 0.8$, large).[9] An alpha level of 0.05 was adopted and all analyses were performed using the Statistical Package for Social Sciences software (SPSS, IBM).

Results

All participants were able to advance with the non-pedal tricycle on a straight path at a self-selected comfortable speed. Table 1 presents the mean (±SD) values of spatial-temporal variables. There was no difference between young and older adults regarding mean speed and stride length. However, older adults had a higher cadence (mean difference of 17 steps/min; 95% CI = 0.99–1.15) and a longer stance duration (mean difference of 3.4%; 95% CI = 56.2–59.5) than young adults.

Fig. 2 presents the mean (±SD) of pelvis, hip, knee, and ankle joint angle profiles in the sagittal plane for the younger and older adults moving on the non-pedal tricycle. Qualitatively, the pattern of the pelvis segment and of all joints was similar between groups. Both younger and older adults maintained the pelvis with approximately 20° of anterior tilt throughout the stride phase due to their adopted position on the saddle (Fig. 2A and E). The younger adults adopted a more flexed position for the hip joint (Fig. 2B) as older adults tended to extend it almost to the neutral position (0°) at the end of stance phase (Fig. 2F). Younger adults maintained their knee joint flexed throughout the stride phase and had approximately 60° of maximum flexion in the swing phase (Fig. 2C). On the other hand, older adults maintained an almost neutral position during the stance phase for the knee joint, and although they presented an accentuated flexion in the swing phase, their maximum knee flexion was approximately 50° (Fig. 2G). Finally, the pattern of ankle joint was roughly similar between groups during the stride cycle, although young adults showed higher dorsiflexion at foot contact to the ground (0% and 100% of stride) than older adults (Fig. 2D and H).

Table 2 presents the mean (±SD) values of joint angles of younger and older adults. For range of motion, older adults had higher excursion at the hip joint (mean difference of 12°; 95% CI = 28–33) and lower excursion at the knee joint (mean difference of 6°; 95% CI = 47.9–53.8) than younger adults, but revealed no difference between groups for the ankle joint excursion. There was no difference between groups for maximum hip extension, but older adults had lower maximum knee flexion than younger adults (mean difference of 9°; 95% CI = 50.8–57.9). Finally, there was no difference between groups for maximum ankle dorsiflexion and maximum plantar flexion.

Discussion

The aim of this study was to describe how younger and older adults use a non-pedal tricycle to transport their bodies along a pathway. Overall, both groups of younger and older adults were able to use the non-pedal tricycle to move from one position to the other along the defined pathway. In doing so, both groups presented similar mean speed, stride length, maximum hip extension, and ankle joint excursion.

Table 1 Mean (±SD) values and effect size of spatial-temporal outcome measures for younger and older adults during the stride cycle of locomotion using a non-pedal tricycle.

Spatial-temporal outcome	Younger	Older	p Value	d_{Cohen}
Mean speed (m/s)	0.87 ± 0.12	0.92 ± 0.22	0.516	0.28
Stride length (m)	1.13 ± 0.11	1.02 ± 0.19	0.149	−0.71
Cadence (steps/min)	92 ± 10.6	109 ± 12.9	*0.010*	1.44
Stance duration (%)	56.2 ± 3.51	59.6 ± 3.07	*0.044*	1.03

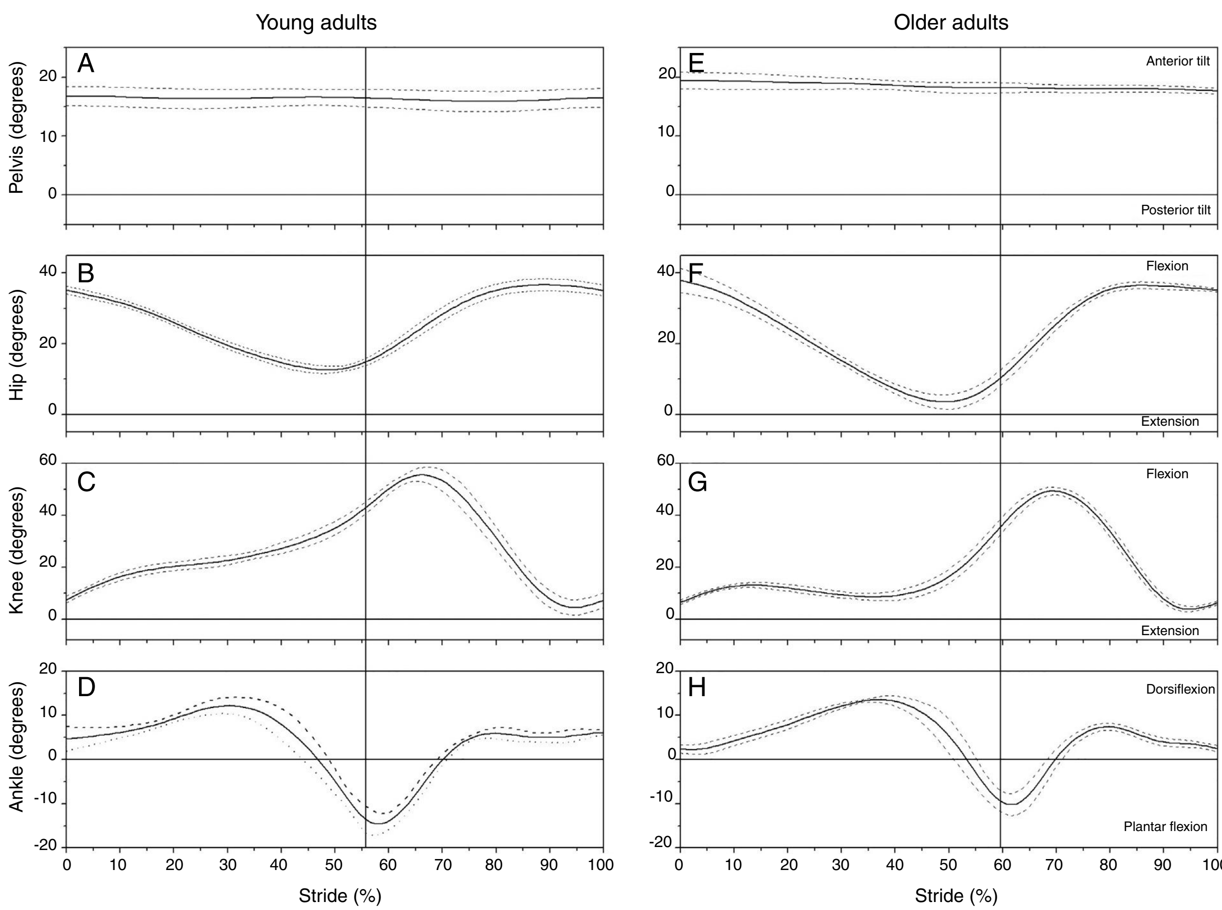

Figure 2 Mean (±SD) stride cycle of pelvis (A, E), hip (B, F), knee (C, G) and ankle (D, H) angles in the sagittal plane for the younger (left panel) and older (right panel) adults moving with the non-pedal tricycle. *Note*: Vertical line indicates the transition between stance and swing periods.

Table 2 Mean (±SD) values and effect size of joint angles for younger and older adults during the stride cycle of locomotion using a non-pedal tricycle.

Joint angles (°)	Younger	Older	p Value	d_{Cohen}
Range of motion				
Hip	25 ± 6	37 ± 4	*<0.001*	2.35
Knee	54 ± 5	48 ± 6	*0.029*	−1.09
Ankle	33 ± 10	29 ± 8	0.449	−0.44
Maximum hip extension	13 ± 12	3 ± 9	0.051	−0.94
Maximum knee flexion	59 ± 9	50 ± 5	*0.025*	−1.24
Maximum ankle dorsiflexion	14 ± 4	16 ± 4	0.277	0.5
Maximum ankle plantar flexion	−18 ± 10	−13 ± 7	0.511	0.58

However, older adults had a higher cadence, longer stance duration, higher hip excursion, and lower knee excursion than younger adults. Based on these results, one could suggest that despite using strategies with minor differences, participants from both groups were able to take advantage of using the non-pedal tricycle, which reveals its feasibility in exercise protocols and as means of transportation for older adults.

The adoption of similar stride length and speed by both younger and older adults using the non-pedal tricycle was surprising. Usually, older adults walk slower and with shorter stride lengths than young adults,[10–12] but this was not the case with the non-pedal device. Such results indicate that older adults, who might have some gait limitation, could take advantage of the device to improve their locomotion capability. Although this suggestion needs to be further examined, the fact that none of the participants had previous experience with the non-pedal tricycle but were all able to use it similarly, employing similar moving speed, as a transport aid, is important and promising. The non-pedal tricycle could be an innovative solution in promoting and expanding transportation options for older adults, although it still needs to be further explored and studied. Moreover, the low variability of the joint profiles (Fig. 2) is an important issue because the non-pedal tricycle allowed locomotive possibilities for both younger and, more importantly, older adults but also constrained lower limb movement in a very stable and similar behavior.

Despite having similar stride length and speed, older adults had a higher cadence and longer stance duration than younger adults. Such differences indicated that older adults adopted a slightly different strategy than younger adults in order to move the non-pedal tricycle forward. Moreover, although the stance period duration that younger adults employed was slightly lower than for walking, these results indicated that both groups adopted a similar temporal organization to move using the non-pedal tricycle, with the percentage of stance duration superior to the swing duration when compared to their walking pattern.[13,14] In future studies, different speeds should be considered in order to verify whether the speed that participants move when using a non-pedal tricycle could influence the temporal organization.[14]

It is important to address that different from walking, in which two-thirds of the body mass (i.e. head, trunk, and arms) is balanced over two moveable legs,[15] the non-pedal tricycle used in this study provided a saddle in which participants could support their body weight as they alternatively move their lower limbs. Consequently, locomotion with the non-pedal tricycle could be an alternative strategy used by individuals who have difficulty fully bearing their body weight during locomotion due to lower limb weakness, which is often one of the reasons for falls in the older population.[16]

The use of a saddle on the non-pedal tricycle is also important to prevent and provide stabilization of the pelvis. The results showed that the excursion of the pelvis was minimal during the movement task and it remained stable as participants alternately moved their legs. This is an important issue as older adults might suffer from hip impairments,[17,18] demanding intervention and high financial costs.[19] However, younger and older adults adopted different strategies in order to move the non-pedal tricycle forward; older adults showed more hip and less knee excursion than younger adults. During walking, the swing limb must be shortened to allow foot clearance; knee flexion is the main movement to attain this shortening.[8,20] During the use of the non-pedal tricycle, older adults seem to have adopted a slightly different strategy as they increased hip and decreased knee excursions. This might be due to the support effect of the saddle allowing longer time for the stance and propulsion phases, and more hip and less knee range of motion. It is important to activate the flexor muscle group of the hip joint to keep the gait safer for older adults,[18,21] and the use of a non-pedal tricycle seems to provide that stimulation to this population. This aspect is also related to the hip extension during movement with the non-pedal tricycle, mainly if one considers that elderly fallers have reduced hip extension during walking.[18] The fact that the non-pedal tricycle allowed excursion of lower limb joints due to the activation of all muscles that cross hip, knee, and ankle joints, one could suggest that a physical exercise program using the non-pedal tricycle could be appropriate to preserve walking performance in older adults[22] and to avoid the higher fall incidence in this population.[18]

This study was the first attempt to describe how younger and older adults use a non-pedal tricycle to transport their body and certainly presents several limitations. The authors investigated the procedure with a non-pedal tricycle only at a comfortable speed and different speeds could be adopted during the task performance. The distance available to conduct the kinematic evaluation was not long enough for testing higher speeds. Additional variables could be investigated as well as the upper body limbs, but the available space was not sufficient to use and register reflective markers on upper limbs in this study. One aspect that could be interesting to investigate in future studies is the propulsion force, and in this case, different equipment, such as force plates, could be employed. Finally, only healthy individuals took part in this study. For future studies, it would be important to examine populations with different health conditions and different ages, especially older adults in their 70s and 80s. Despite these limitations, the results revealed that it is feasible to use a non-pedal tricycle for older adults and more studies should be conducted to investigate the possible benefits of the non-pedal tricycle in physical exercise protocols.

Conclusion

The results of this study showed that older adults are able to transport their body using a non-pedal tricycle. However, older adults adopted some different strategies than younger adults to move along a straight pathway, mainly in terms of hip and knee excursions. Professionals who work with the older population should consider using non-pedal tricycles in physical exercise protocols and investigate its long-term impacts.

Conflicts of interest

The authors declare no conflicts of interest.

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