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Performance of hemiplegic patients in 180º turns in the direction of the paretic and non-paretic sides before and after a training program

Desempenho de hemiplégicos no giro de 180º realizado em direção ao lado parético e não parético antes e após um programa de treinamento

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Abstract

Objective: To investigate the performance of hemiplegic patients in 180° turns before and after a training program which is effective in improving other functional tasks, considering the effect of the turning direction. **Methods:** Thirty chronic hemiplegics (17 men and 13 women; 56.36±10.86 years) participated in a training program (aerobic activities and muscular strengthening) and were evaluated before and after the intervention by means of the Step/Quick Turn (SQT; Balance Master®), which involves a 180° turn during gait. Gait velocity and stair climbing ability were also evaluated. Mixed repeated-measures ANOVA (2x2) was used to compare the turning direction (paretic and non-paretic) and the pre- and post-intervention evaluations. Paired *t* tests were used to investigate the impact of the training program on gait velocity and stair climbing ability (α=0.05). **Results:** No significant differences were found in any of the SQT variables when considering the turning direction (0.23<p<0.81; 0.06<*F*<1.48). However, there was a significant improvement in the time taken to execute the turn (p=0.01; *F*=6.90), regardless of the turning direction (p=0.56; *F*=0.34), in gait velocity and in stair climbing ability (p<0.001). **Conclusions:** The training program, which is effective in improving gait velocity and stair climbing ability, was also effective in reducing turn execution times regardless of turning direction: turns in the direction of the paretic side were similar to turns in the direction of the non-paretic side.

Key words: hemiplegia; functional performance; turn.

Resumo

Objetivo: Investigar o desempenho de hemiplégicos no giro de 180º antes e após um programa de treinamento, o qual foi eficaz na melhora do desempenho de outras atividades funcionais, considerando o efeito do lado em direção ao qual o giro foi realizado. **Métodos:** Trinta hemiplégicos crônicos (17 homens/13 mulheres; 56,36±10,86 anos) participaram de um programa de treinamento (atividades aeróbicas e de fortalecimento muscular) e foram avaliados pré/pós intervenção pelo teste *Step Quick Turn* (STQ/*Balance Master*®), que envolve a atividade de giro de 180º durante a atividade de marcha. Também avaliou-se a velocidade da marcha e a habilidade para subir escadas. ANOVA mista com medidas repetidas (2x2) foi utilizada para comparação entre a direção de giro (lado parético e não parético) e as avaliações pré e pós-intervenção. Testes-t pareados foram utilizados para investigar o impacto do treinamento na velocidade da marcha e habilidade para subir escadas (α=0,05). ANOVA mista com medidas repetidas (2x2) foi utilizada para verificar efeitos principais e de interação entre o lado em direção ao qual o giro foi realizado e as avaliações pré/pós intervenção e testes-t pareados para investigar o impacto do treinamento na velocidade da marcha e habilidade para subir escadas (α=0,05). **Resultados:** Não houve diferença significativa para nenhuma das variáveis do SQT quando se considerou o lado de realização do giro (0,23<p<0,81; 0,06<*F*<1,48). Entretanto, houve melhora significativa no tempo para realizar o giro (p=0,01; *F*=6,90), independente do lado em que o mesmo foi realizado (p=0,56; F=0,34), na velocidade da marcha e na habilidade para subir escadas (p<0,001). **Conclusões:** O programa de treinamento, eficaz na melhora da velocidade da marcha e na habilidade para subir escadas, foi eficaz também na melhora do tempo de execução do giro, independente do lado para o qual o mesmo foi realizado: o giro em direção ao lado parético foi semelhante ao giro para o lado não parético.

Palavras-chave: hemiplegia; desempenho funcional; giro.

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Introduction

Cerebrovascular accident (CVA) or stroke is one of the major causes of chronic disability in the world and one of the health conditions that receives the most attention by public health care services[1]. Among the various disabilities caused by stroke, motor disabilities are the most prevalent and have the greatest functional impact. Hemiparesis/hemiplegia is the most common motor disability, present in approximately 75% of individuals affected by stroke, and it is considered an important factor in the changes in mobility observed in this population[2]. Individuals with hemiparesis/hemiplegia after stroke are traditionally called hemiplegics[3,4] therefore this will be the term adopted to refer to these individuals throughout the text.

Several studies have been carried out to investigate the performance of hemiplegics in different functional mobility tasks, such as gait[3,4], sit-to-stand movements and stand-to-sit movements[5,6]. However, other important mobility tasks which are commonly performed by these individuals have not been investigated. One is the 180º turn[2], characterized as a complex task involving specific sensory-motor skills[7] and often performed by hemiplegics[2] during activities of daily living (ADLs)[2,7]. During gait, individuals usually perform a 180º turn to return to a specific place or position, to sit on a chair, to avoid obstacles, etc[2,7]. Thus, the 180º turn is an important functional task and should be evaluated and addressed properly by professionals in the field of rehabilitation.

In the elderly population[8] and in individuals with Parkinson's disease[9], limitations or difficulties in executing the 180º turn increase the risk of falls. Moreover, falls during the turn increase by eightfold the likelihood of hip fractures in the elderly population[10]. No information was found on the impact of difficulties in executing the 180º turn in hemiplegics, however the previous data are of particular concern given the high incidence and prevalence of stroke in elderly individuals[11] and the high incidence of falls in individuals with a history of stroke[12,13].

According to Mackintosh et al.[13] and Hyndman, Ashburn and Stack[14], falls in hemiplegics often occur in the direction of the paretic side, which denotes a reduction in bone mineral density[15]. Thus, studies on the performance of the 180º turn by hemiplegics should be carried out not only because the turn is an important functional task, but also because it is often associated with falls[9] that lead to bone fractures, costly health care, and a negative impact on individuals' lives[12,13].

Considering the characteristics of the physical disabilities of hemiplegics and their direct relationship with the reduction in mobility in these individuals[2], the importance of the 180º turn to functionality[2,7] and the association between turning difficulties and increased risk of falls in the elderly[8], the purpose of this study was to investigate the performance of 180º turns by hemiplegics before and after a physical training program already shown to be effective in improving various components of human functionality, considering the effect of the turning direction (turns in the direction of the paretic side compared to turns in the direction of the non-paretic side). To characterize the effectiveness of the physical training program[16,17] specifically in mobility tasks such as the 180º turn, the results for gait velocity and stair climbing ability were also reported.

Methods

Sample

Thirty-nine community-dwelling participants were recruited in the city of Belo Horizonte. The participants were over 20 years of age and had motor sequelae as a result of ischemic or hemorrhagic stroke. To participate in the study, the following inclusion criteria were considered: time lapse of at least nine months since last stroke episode; weakness and/or spasticity on the paretic body side; ability to walk independently for 15 minutes, with rest intervals and the help of mechanical aids (except walkers) if needed; ability to exercise for 45 minutes with rest intervals; a doctor's certificate authorizing physical activity; ability to follow the test and training instructions, and availability for 12 consecutive weeks. The exclusion criterion was the presence of bilateral hemiparesis/hemiplegia. All participants signed an informed consent form pre-approved by the Research Ethics Committee of Universidade Federal de Minas Gerais (approval 031/99). A total of eight participants were excluded: four due to insufficient attendance and four due to constant changes in blood pressure.

Instrumentation and procedures

All participants were initially evaluated to verify the inclusion criteria and to collect demographic and clinical data, such as age, sex, time elapsed since stroke, affected side, medication and use of orthoses and/or walking aids. After the clinical assessment, all participants were evaluated to determine the performance in the 180º turn and to characterize the functional performance in other activities. This evaluation was performed twice: immediately before the start of the intervention program and immediately after its completion.

180º turn performance

The evaluation of the 180º turn was carried out according to the standardized protocol of the Step Quick Turn (STQ) test from the Balance Master® System (NeuroCom® International, Inc.)[18], which has been used for balance assessment[19] and training[20] of individuals with a history of stroke. The Balance Master® is a device designed to diagnose and train balance and mobility skills, and it consists of a computer and a system of dual forceplates (0.46m by 0.23m each) with four force sensors capable of detecting pressure at a frequency of 100 Hz. The center of pressure of the individual on the forceplate is estimated, considering the generated vertical force. Finally, all the information captured by the forceplate system is sent to a computer connected to the device and the software provided by the manufacturer for processing[18].

Different psychometric properties have been investigated for the Balance Master® protocols and acceptable results were established[21-24], including the use of the device by individuals with a history of stroke[22,24] and for the SQT test[23]. This test has been used to evaluate the performance of 180º turns in different populations[21,23,25,26]. As demonstrated by Ben Achour Lebib et al.[21], the tests proposed and standardized by the Balance Master® System (including the SQT test and its protocols and variables) are valid not only for postural balance assessment, but also for evaluating physiological conditions that can limit the performance of important ADLs, such as gait, 180º turns and sit-to-stand movements, thus differentiating between individuals with and without risk of falls. According to the standardized SQT test protocol[18], the participant was asked to take two steps forward, turn 180º, and return to the starting position. Even though the turn is carried out during gait, the device only gives the variables of the turn time, starting when forward progression of the center of gravity (COG) stops and ending when forward progression in the opposite direction begins.

All variables provided by the SQT test were considered for analysis[18]:

- turn time (in seconds), which is measured from the moment forward progression of the center of gravity stops until the moment forward progression in the opposite direction begins[18];
- average COG sway (in degrees) during the turn. To measure this variable, the software calculates the position of the COG based on the participant's height provided before the data collection. The distance traveled by the COG during the turn is measured in degrees, considering the participant as an inverted pendulum (in which the axis is marked by the support foot) and the turn direction. For example, if during a turn to the right the COG shifts 10° to the right, 2º backwards and 7º to the left with support foot and turn direction as a reference, the total distance traveled by the center of gravity is 10º + 7º - 2º, totaling 15º[18];
- the turn time ratio to either side (in percentage). This ratio is calculated using the following equation: [(longest turn time - shortest turn time)/(longest turn time + shortest turn time) x 100][18];
- average COG sway ratio to either side (in percentage). This ratio is calculated using the following equation: [(greatest average COG sway - least average COG sway)/(greatest average COG sway + least average COG sway) x100][18].

Before data collection, the participants were familiarized with the SQT protocol by performing the test twice, alternating turn directions. After that, the data was collected for analysis. Each participant performed three repetitions of the SQT test turning to the right and three repetitions turning to the left, according to the device protocol[18]. The average of the three repetitions was used for analysis, considering the turn executed in the direction of the paretic side or the non-paretic side. Therefore, if the right side of the participant was the paretic side, the performance of the right turn was termed the performance of turning in direction of the paretic side, and vice versa.

Gait velocity

Gait velocity has been considered an important measure of functional performance in hemiplegics, with appropriate values of reliability. It has also been shown to be sensitive to evaluate functional gains in this population[27]. This test is one of the most used for functional performance evaluation of hemiplegics, both in clinical and in research contexts[27]. To determine gait velocity, the participants were asked to walk a distance of 28m at a "comfortable" speed in everyday shoes, and they were allowed to use orthoses and walking aids, if necessary. The time taken to cover the central 24m was measured with a digital stopwatch, and gait velocity was calculated in m/s. The average of three repetitions was used for analysis.

Stairs climbing ability

Stair climbing ability has also been considered an important measure of functional performance in hemiplegics[27]. To determine stair climbing ability, participants were asked to climb a flight of stairs with six steps of about 15cm each at a "comfortable" speed and wearing everyday shoes. Participants were allowed to use orthoses, walking aids and handrail support, when necessary. As in a previous study[27], the time taken to climb the six stairs was measured with a two-digit stopwatch, starting from the moment the first foot touched the first step and ending when the last foot touched the base of the stairs, once it left the last step. After that, the climbing cadence was calculated and expressed in steps/minutes. The average of three repetitions was used for analysis[27].

Training program

The training program involving muscle strengthening and aerobic conditioning was conducted in a weight-training laboratory over ten consecutive weeks, with three weekly sessions of 120 minutes each on average. The sessions were conducted in groups, supervised by physical therapists and accompanied by music appropriate to the activities and the age of the participants. Heart rate was constantly monitored and recorded, along with blood pressure readings, before and after the activities.

The physical training program followed a protocol of activities already used with chronic hemiplegics[3] and detailed in a previous study[16]. This consisted of: (1) a five to ten-minute warm-up including stretching, range of motion, and calisthenics exercises; (2) 30 to 40 minutes of aerobic exercise including walking and cycling, with each activity graded to achieve at least 70% of the maximum heart rate according to age; (3) muscle strengthening exercises using weight training equipment, and (4) a period of relaxation, consisting of muscle stretching[16].

Statistical analysis

All statistical analyses were performed using SPSS for Windows (version 15). Descriptive statistics and normality tests (Shapiro-Wilk) were performed for all variables. Paired *t* tests were used to investigate the impact of the training on gait velocity, on stair climbing ability and on the variables of time ratio and average COG sway provided by the SQT test. Mixed repeated-measures ANOVA (2x2) was used to compare the other variables related to the SQT test, considering the turning direction (paretic or non-paretic side), and to compare these variables pre- and post-intervention.

Results

Sample characteristics

Thirty participants, 17 men and 13 women between 34 and 83 years of age (mean age 56.36±10.86 yrs) completed the training program. The time lapse since stroke ranged from one to 14 years (3.81±3.37 years) and half of the participants had motor impairments on the right side of the body. Fifteen participants used walking aids and ten, ankle/foot orthoses.

180º turn performance

The mean, standard deviation and range [minimum-maximum] of the variables related to the SQT test performance, both pre- and post-intervention are shown in Table 1.

Considering the turning direction, the average turn time (p=0.81, F=0.06) and the average COG sway (p=0.23, F=0.81) were not significantly different when the performance of the turn in the direction of the paretic side was compared to the performance in the direction of the non-paretic side.

After the physical training program, there was a significant decrease in the turn time (F=6.90; p=0.01), regardless of the direction of the turn (F=0.34; p=0.56). In contrast, the average COG sway did not show statistically significant changes after the physical training program (F=0.01; p=0.99), regardless of the turning direction (F=0.06; p=0.81). The average turn time ratio and the average COG sway ratio also showed no statistically significant changes after the intervention (p=0.10 and p=0.20, respectively).

Performance in other functional activities

As can be seen in Table 1, significant differences were observed for both gait velocity and stair climbing ability after the training program (p<0.0001).

Discussion

The direction of the 180º turn (toward the paretic or non-paretic side) did not have a significant effect on the performance of the task, which was conducted according to the SQT test protocol of the Balance Master System®. The turn in the direction of the paretic side showed similar values to the turn in the direction of the non-paretic side as regards turn time and average COG sway. Moreover, for all variables, the turning direction was not a significant interaction factor with regard to the results of the different assessment moments.

After the training program, the turn time was significantly shorter, and the average COG sway did not undergo significant changes, regardless of the turning direction. Another result that emphasized the lack of effect of the turning direction on the performance of this task was the similarity between pre- and

Table 1. Descriptive statistics (mean, standard deviation and range [minimum and maximal values]) of the Step/Quick Turn variables pre- and post-intervention (n=30).

Variable		Pre-intervention	Post-Intervention	*p*
Turn in the direction of paretic side	Turn Time (s)	3.66±1.73 [1.34–7.74]	3.29±1.25 [0.96–6.21]	0.01*
	COG Sway (°)	56.40±14.14 [31.50–80.80]	56.68±14.96 [27.90–98.80]	0.99
Turn in the direction of non-paretic side	Turn Time (s)	3.68±1.59 [0.98–7.21]	3.44±1.24 [0.84–6.37]	0.01*
	COG Sway (°)	55.44±15.08 [20.90–97.30]	52.13±13.24 [20.50–84.80]	0.99
Turn Time Ratio (%)		9.50±7.67 [0.00–39.00]	6.53±4.65 [1.00–16.00]	0.10
COG Sway Ratio (%)		7.87±7.10 [0.00–26.00]	5.93±4.70 [0.00–22.00]	0.20
Gait Velocity (m/s)		0.69±0.35 [0.18–1.45]	0.89±0.38 [0.26–1.66]	0.0001*
Stair Climbing Ability (steps/min)		48.20±24.00 [15.93–106.82]	56.60±26.70 [18.77–122.45]	0.0001*

*p<0.05.

post-intervention turn time ratios and COG sway ratios for either side. Nonetheless, it is worth noting that the training program was effective in improving the time to accomplish this task, gait velocity and stair climbing ability.

Another important point to note is that we found no other studies investigating the performance of the 180º turn by hemiplegics. This has limited the comparisons and discussions of the present results in light of previous findings. However, some important points will be discussed below to provide a better understanding of the performance of 180º turns by hemiplegics, given the complex nature of the task and its importance to functional mobility[2,7]. This discussion may also guide the development of future studies on the performance of this particular task by hemiplegics.

Turns in the direction of the paretic side versus the non-paretic side

Given the characteristics of hemiplegia and the nature and severity of this disability, a clinical conclusion that could be drawn regarding the performance of 180º turns by hemiplegics is that the variables would behave differently when the task was executed in the direction of the paretic side compared to the non-paretic side. In the Balance Master® manual, a similar reasoning is used: individuals with lower limb asymmetry may have different SQT test performances when comparing sides of the executed test[18]. Such reasoning can be based on the following premises: first, that the motor deficits of individuals with a history of stroke reflect the type, location and extent of the vascular injury; that hemiparesis/hemiplegia is more common in individuals with a history of stroke and a primary indication for rehabilitation[2]; and, finally, that several studies have highlighted significant differences between the paretic and non-paretic sides in the performance of functional tasks and the relationship between these differences and the individual's functional level[4,6].

Despite the consistency of all of these premises, the present study results did not support the reasoning that there is a direct relationship between 180º turn performance and turn direction. The two variables used to assess the turn, i.e. turn time and average COG sway, were similar when the task was executed in the direction of the paretic and non-paretic side. Moreover, the turning direction was not a significant interaction factor between pre- and post-intervention assessments for all variables.

Although the individuals affected by stroke have greater motor changes in the body side contralateral to the cerebral hemisphere affected by stroke, the ipsilateral side is also affected either by direct consequences of the brain injury, given that a small part of the nerve fibers does not cross at the pyramidal decussation in the brainstem[28], or by compensations developed after the limitations suffered by the paretic body side[2,5,29,30]. Thus, both body sides are affected by stroke in one way or another and have some degree of change in muscular and motor control during task performance[5,29,30]. Despite this evidence of the effects of the brain injury on the ipsilateral body side, it is important to note that the paretic side is significantly more affected in these individuals, which characterizes the hemiparesis[2], and all participants were hemiparetics, with significant differences in strength and muscle tone between the paretic and non-paretic sides, particularly the paretic side[16]. Thus, one would expect that such differences would result in different performances when the 180º turn was executed in opposite directions.

According to the Biopsychosocial (BPS) Model of Health and Illness, on which the International Classification of Functioning, Disability and Health is based, the one-to-one ratio present in the abovementioned reasoning (different 180º turn performance according to turning direction) is insufficient, and recent studies have illustrated this[31,32]. The BPS model has been considered the most suitable for understanding the process of human functioning and disability in diseases that affect different dimensions of health[33], as is the case of stroke[34]. This is because it takes into account the dynamic, complex and random interaction in a health condition, the context and the components of structure and body function, activity and participation. This shift in paradigm has resulted in a broader understanding[34,35] and may assist in the interpretation of the present results. Other factors not directly related to hemiparesis/hemiplegia may influence the performance of the 180º turn. Considering the results of the present study, the turn direction may not be an important control variable in rehabilitation to improve the 180º turn performance of hemiplegics or in future studies on their performance of this task. However, as this was the first study to report the performance of 180º turns by hemiplegics further investigations are needed to corroborate this evidence.

Effects of the intervention program on 180º turn performance

The training program was not only effective in improving different components of human functionality[16,17] but also in improving turn time. This result is even more important if we consider that the assessment of the 180º turn was similar to what is commonly performed during ADLs[36]. In the SQT test, the 180º turn is performed during gait in a sequence of gait - 180º turn - gait. Not only was this sequence similar to that of ADLs, but it was also more challenging than the 180º turn alone as it combines the anticipation of forward deceleration of the COG, a change in step pattern and the initiation of gait in the opposite direction[18,36].

According to Thigpen et al.[37], an average time of more than three seconds to accomplish the 180º turn is an indicator of turning difficulty in elderly individuals. In the present study, the average turn time was greater than three seconds, regardless of the moment of assessment (pre- and post-intervention) and the conditions in which the task was executed (turn in the direction of the paretic or the non-paretic side). If we consider the reference value proposed by Thigpen et al.[37], the participants of the present study had turning difficulty in all of the assessments. However, this reference value was proposed for elderly individuals, and the present study participants were hemiplegics. Despite this limitation in classifying the level of difficulty of the participants, it can be stated that this difficulty decreased with the training program, since the turn time was significantly shorter.

The time taken to perform any task is inversely related to the velocity of execution: individuals who perform the turn in a shorter time execute the task at a higher velocity and those who perform the turns in a longer time execute the task at a lower velocity. Turning safely at high speed requires adequate control of COG sway over the basis of support[38]. The results of the average COG sway during the turn, regardless of the moment of evaluation (pre- and post-intervention) or of the turn direction (toward the paretic or non-paretic side), revealed a large amount of COG sway in all assessment conditions[38]. The need to control COG sway during the turn in both directions may have required that the task be performed at a lower velocity. Nevertheless, the training program was effective in significantly decreasing the time taken to execute the 180º turn, even without a significant change in the average COG sway.

Thus far, two main strategies have been identified for the 180º turn during gait: turning in the direction contralateral to the support foot and turning in the direction ipsilateral to the support foot[36,39]. The strategy of turning in the direction ipsilateral to the support foot can be subdivided into two substrategies: the ipsilateral pivot and the ipsilateral crossover[39]. The ipsilateral turn strategy requires greater muscular demand and range of motion in the transverse plane than the contralateral turn strategy, which in turn provides a more stable support base, does not require increased coordination and is no more biomechanically demanding than straight gait[39].

With regard to the SQT test protocol, the strategy used by the participants in the present study was to turn in the direction ipsilateral to the support foot. Because this strategy is more biomechanically demanding than straight gait, it may have influenced the results. The intervention was effective in improving the performance time, the gait velocity and the stair climbing cadence, but was not effective in improving the average COG sway during the 180º turns. If the participants had been allowed to self-select the turning strategy during the test, the results of the comparison between pre- and post-intervention average COG sway may have been different.

Another important factor that could explain the absence of changes in this variable after the intervention is related to the specificity of the intervention. The training program did not include the turning task and was not specifically aimed at training dynamic balance. Nonetheless, there were improvements in one of the outcomes used to characterize the 180º turn performance, i.e. the time taken to execute the test. As previously mentioned, this involves a sequence of activities similar to what is routinely performed by individuals, with a high level of difficulty when compared to the execution of the turn alone. Similar results were reported by Clary et al.[25] who investigated the effect of three intervention programs (ballates, step aerobics and walking) on the balance of healthy women between 50 and 75 years of age. All balance assessments were performed on the Balance Master®. Although none of the interventions were specifically designed for dynamic balance training, there were significant improvements in the SQT test variables in the three groups investigated, without differences between groups.

For hemiplegics, the SQT test using the Balance Master® imposes certain execution conditions that may have hindered the adoption of more efficient strategies to perform the 180º turn as discussed previously and, therefore, required similar amplitudes of average COG sway for the task. In contrast, for the healthy individuals, as was the case of the study by Clary et al.[25], the execution of the SQT test according to the device protocol may not have prevented the adoption of effective strategies, which allowed the execution of the task with less COG sway. However, it is necessary to develop a specific study to answer these questions. In the present study, the use of the SQT test according to the prescribed protocol was necessary to standardize the test conditions, as one of the aims was to compare the turn performance in the direction of the paretic and non-paretic sides. The protocol also provided objective measures for the turn performed during gait, which could not have been obtained using other available forms of measurement.

Conclusions

The present training program was effective in decreasing the time required to execute the turn, regardless of the turning direction, and in improving gait velocity and stair climbing cadence. The performance of the 180º turn in the direction of the paretic side was similar to the performance in the direction of the non-paretic side, and both directions showed similar changes after the physical training program.

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