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BODY-MIND PHYSICAL EXERCISE AFFECTS WALKING DURING DUAL TASK: A PRELIMINARY STUDY

L'ESERCIZIO FISICO CORPO-MENTE INFLUENZA IL CAMMINO DURANTE IL DOPPIO COMPITO: UNO STUDIO PRELIMINARE

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Abstract

Walking is a task that is typically performed simultaneously with other tasks. This condition recalls the same features of an experimental paradigm known as "Dual Task" (DT), which is an excellent strategy for investigating the role of cognitive functions during walking. Current research is focusing on what are the best strategies for enhancing DT skills. From these researches it emerged that physical exercise (PE) is an excellent ecological strategy capable of directly acting on both motor and cognitive functions. In the present study, we investigated the influence of unimodal and multimodal PE on the ability to walk while performing a DT paradigm. For this purpose, a 3D motion analysis was performed in three groups of participants: Tai Chi, runners and naïve control groups. Participants were asked to walk while performing simultaneously a motor or cognitive secondary task. The harmonic ratio, a synthetic index able to provide information on dynamic stability and fluidity of movements during walking, was calculated. The results showed that the HR of the trunk in medio-lateral direction was significantly lower both in runners and controls than in the Tai Chi practitioners group. The cognitive task seems to have a greater weight than the motor one. Finally, the results showed that the Tai Chi group has a better ability to perform cognitive DT than the other groups. The results of this study support the improvements in executive function induced by Tai Chi practice.

Il cammino è un'attività che viene in genere eseguita contemporaneamente ad altre attività. Questa condizione richiama le stesse caratteristiche di un paradigma sperimentale noto come "Dual Task" (DT), che rappresenta un'ottima strategia per indagare il ruolo delle funzioni cognitive durante la deambulazione. La ricerca attuale si sta concentrando su quali sono le migliori strategie per migliorare le abilità di DT. Da queste ricerche è emerso che l'esercizio fisico (EF) è un'ottima strategia ecologica in grado di agire direttamente sia sulle funzioni motorie che cognitive. Nel presente studio, abbiamo studiato l'influenza dell'EF unimodale e multimodale sulla capacità di camminare durante l'esecuzione di un paradigma DT. A tale scopo, è stata eseguita un'analisi del movimento 3D in tre gruppi di partecipanti: Tai-Chi, corridori e gruppi di controllo naïve. Ai partecipanti è stato chiesto di camminare mentre eseguivano contemporaneamente un compito motorio o cognitivo secondario. È stato calcolato l'harmonic ratio, un indice sintetico in grado di fornire informazioni sulla stabilità dinamica e sulla fluidità dei movimenti durante la deambulazione. I risultati hanno mostrato che l'HR del tronco in direzione medio-laterale era significativamente più bassa sia nei corridori che nei controlli rispetto al gruppo di praticanti di Tai Chi. Il compito cognitivo sembra avere un peso maggiore di quello motorio. Infine, i risultati hanno mostrato che il gruppo Tai Chi ha una migliore capacità di eseguire il DT cognitivo rispetto agli altri gruppi. I risultati di questo studio supportano i miglioramenti nella funzione esecutiva indotti dalla pratica del Tai Chi.

Key-words
Dual task; Tai Chi; Runners; Physical exercise; Sport;
Dual task; Tai Chi; Runners; Esercizio fisico; Sport;

1. Introduction

Walking is the main form of human locomotion. It requires the ability to adapt to environmental stimuli in order to meet individual aims. Commonly, walking involves the performance of simultaneous cognitive or motor tasks, such as participating in a conversation or carrying objects from one place to another. It is suggested that walking performance does not consist in a series of rote repetitions with each step, as the surrounding environment can be highly variable. Contrary to a traditional view, in which walking was understood as an automatic, reflex-dependent task requiring a low level of cognitive control, recent empirical evidence has shown that walking is a complex task requiring the integration of sensory and cognitive information (Yogev, Hausdorff, & Giladi, 2008). In particular, brain imaging studies revealed the activation of some brain areas mainly involved in a higher cognitive control process that underlies the successful execution of movements (Sheridan & Hausdorff, 2007).

In experimental conditions, the relationship between cognition and movement can be explored through the dual task (DT) paradigm, in which a secondary motor or cognitive task is performed simultaneously with a primary one (Liparoti, 2021a; Yogev et al., 2008). During a dual task, one or both tasks may be impaired, these changes in performance indicate the higher cognitive demand. When the cognitive demand is high, gait may change and the body may be exposed to an increased risk of falling (Minino et al., 2021; Rucco et al., 2018). The ability to correctly perform a DT condition depends on the efficiency of attentional resources, which underlie the successful execution of physical and cognitive tasks. Interference between two tasks suggests that shared attentional resources may involve the regulation of motor and cognitive control, which may be compromised. This is a condition that typically occurs in older adults or those with neurological diseases, who have greater difficulty in managing multiple tasks performed simultaneously (Liparoti et al., 2019). The use of DT methodology to assess the interaction between cognition and movement has been a growing research topic. Specifically, current research is focusing on the best strategies for enhancing dual-task skills. Several studies showed that physical exercise (PE), and in particular aerobic exercise, is an excellent ecological strategy that can directly affect both motor and cognitive functions(Crawford, Caplan, & Loprinzi, 2021; Liparoti, Madonna, & Minino, 2020; Liparoti & Lopez, 2021; Liparoti & Minino, 2021; Troisi Lopez, Cusano, & Sorrentino, s.d.; Loprinzi, Moore, & Loenneke, 2020). Indeed, the constant practice of PE induces neuroplasticity phenomena and this represents an important neuroprotective factor in the acquisition of cognitive reserves, in preserving or delaying cognitive decline (Minino, Belfiore, & Liparoti, 2020; Sorrentino et al., 2021).

The present study focuses on the impact of unimodal and multimodal PE on DT abilities (Liparoti, 2021b). Multimodal PE is a body-mind intervention that leads a conscious control of movement in order to improve physical and psychological well-being (Laird, Paholpak, Roman, Rahi, & Lavretsky, 2018). Among the different types of body-mind intervention, two of the most popular are Tai Chi (TC) and Yoga. Several evidences showed that the

multimodal PE contribute to improving motor function (balance, stability, flexibility of movements), mental health (acting on stress, anxiety and depression) and acquiring cognitive abilities or delaying its decline (Hackney & Wolf, 2014; C. Wang et al., 2010; F. Wang et al., 2014). Unlike multimodal exercises, unimodal exercises involve conventional aerobic exercises, usually aimed at improving muscular strength and endurance (e.g. running, gymnastics, swimming and cycling), and do not include structured cognitive interventions. The unimodal PE seems to have an effects on brain both in structure and function (Chang, Tsai, Wang, & Chang, 2015).

Although evidence above mentioned shows the influence of both unimodal and multimodal PE on motor and cognitive functions, there is a significant knowledge gap regarding the benefits induced by exercise on DT ability and how this may need to improve mobility, balance and cognitive functions, as well as reducing falls. Filling this knowledge gap is important for the development of personalised and adapted exercises useful to improve dual-task ability, which may have great relevance in maintaining independence and a better quality of life at all age. To clarify this topic, in this study was investigated the influence of unimodal and multimodal PE on the ability to perform a DT experimental paradigm. For this purpose, were selected three participant groups, TC practitioners, runners and naïve people, who performed a cognitive and motor DT.

2. Methods

Participants

Eleven runners, eleven TC practitioners and eleven age-matched naïve control groups were voluntarily recruited, according to the following criteria: aged > 18 years; normal cognitive function as indicated by the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) score of ≥ 26; any cardiovascular, neurological or musculoskeletal diseases; any anxiety symptoms as indicated by Hamilton Anxiety Scale (Hamilton, 1959) scores and any history of drug or alcohol abuse. Written informed consent was obtained from all participants. In Table 1 are reported the participants' features.

Table 1. Demographic and anthropometric features.

Features	Tai Chi	Runner	Control	p value
Age (years)	56 ± 6.6	49 ± 6.9	52.8 ± 8.1	n.s
Gender (m/f)	5/6	10/1	6/5	-
Education (years)	15.3 ± 2.6	15.2 ± 3.3	14.8 ± 4	n.s
BMI (Kg/m^2)	25.7 ± 3.7	23.4 ± 1.8	25.1 ± 2.2	n.s
MMSE	27.9 ± 1	27.5 ± 1.1	27.1 ± 1.4	n.s
Hamilton	5.3 ± 3.6	4.5 ± 5.1	7.5 ± 5.1	n.s

Note: Data are given as mean ± standard deviation.
Abbreviation: BMI, body mass index; MMSE, Mini Mental State Examination, n.s, not significant.

Experimental procedure

The evaluation of DT ability was performed using motion analysis tools at the University of Naples "Parthenope". Specifically, a stereophotogrammetric system (Liparoti, Troisi Lopez, & Agosti, 2020; Sorrentino et al., 2016) equipped with 8 infrared cameras (ProReflex Unit-Qualisys Inc., Gothenburg, Sweden, with a sampling frequency of 120 Hz) was used for gait analysis during DT performance. As in previous studies (Minino et al., 2021; Troisi Lopez et al., 2021), fifty-five passive markers were applied to each participant on anatomical landmarks of the feet, lower limb joints, pelvis, trunk, upper limb joints and head. Participants were asked to perform the following tasks (Liparoti et al., 2019): walking at their preferred walking speed (single task); motor dual task (MotDT, in which participants carrying a tray with two glasses of water while walking); cognitive dual task (CogDT, which consists of counting backwards aloud by subtracting 7s from 100 while walking). Were recorded at least four trials for each task condition. The recorded data were processed using tracking software (Qualisys Track Manager from Qualisys AB, Gothenburg, Sweden) and software (Visual 3D from C-Motion Inc., Germantown, MD) to reconstruct and model the skeleton. To evaluate the difference among groups a synthetic index, called the Harmonic Ratio (HR) (Roche, Lowry, Vanswearingen, Brach, & Redfern, 2013), was calculated. The HR is a useful measure to quantify the smoothness of walking, which is based on a spectral analysis of the acceleration signals, generally acquired at the trunk level in the anteroposterior (AP), vertical (VT) and mediolateral (ML) directions. A high HR score is interpreted as greater walking smoothness.

Statistical analysis

Statistical analysis was performed using MATLAB (Mathworks®, version R2013a). The normal distribution of variables was checked with the Shapiro-Wilk test. In order to compare the three experimental condition (single task, motor and cognitive dual task) of three groups, the analysis of variance (ANOVA) was performed, followed by post-hoc analysis between groups using a paired sample t test. All the *p* values were corrected for multiple comparisons using the false discovery rate (FDR) (Benjamini & Hochberg, 1995). The statistical significance was defined as $p < 0.05$.

3. Results

The ANOVA analysis showed a significant difference of medio-later trunk HR ($p < 0.05$) among groups. In detail, the *post hoc* analysis showed significantly higher scores of medio-later trunk HR in TC practitioners group with respect to the runners ($p < 0.05$) and control naïve ($p < 0.05$). Both CogDT and MotDT paradigms tests the ability to allocate the attention simultaneously to motor and cognitive tasks. The *post hoc* analysis showed significantly higher cost of CogDT as compared to MotDT ($p < 0.05$). Finally, the statistical analysis of interaction between group and condition showed significantly higher scores of medio-later trunk HR during CogDT of the TC practitioners group with respect other groups ($p < 0.05$).

4. Discussion

The present study aimed to examinate the effects of unimodal and multimodal PE (Liparoti, 2021b) on dual task ability during walking in adult people, in order to investigate which one type of exercise mostly affects these abilities.

Analysing the results, it is observed that TC practitioners group showed a better performance, than the group of runners and naïve control group, during the performance of DT, highlighting how multimodal PE improves executive functions (EF) (Yogev et al., 2008). Indeed, dual task is an experimental condition useful to investigate different components of EF considered as "higher level" functions, involving top-down mental processes (Montuori et al., 2019; Sorrentino et al., 2019). These functions are necessary to develop the ability to plan and structure purposeful activities and the ability to adapt to new situations by showing flexibility to changes and displaying problem solving skills, all of which are fundamental aspects for carrying out activities of daily living.

Specifically, results showed that TC practitioners group showed significantly higher scores of medio-later trunk HR during CogDT. Indeed, in this study was asked participants to perform a subtraction task while walking. The n-back task requires the working memory involvement that is defined as an integral component of EF engaged in complex cognitive coordination useful for the activity of daily living, since it allows to shifting attention from one task to another and perform two tasks simultaneously (Serra et al., 2021).

A possible explanation of these finding could be that TC requires practitioners to pay attention and remember a long sequence of movements, usually 24 to 108 forms (Robins, Elswick, & McCain, 2012). The TC is a multimodal activity, which besides training motor functions through the typical movements of martial arts and induces an improvement of cognitive functions as it includes meditative components. Qui and Yi (breath and mind respectively) are two important elements of TC exercise that are the basis of yogic relaxation through deep breathing. TC is considered a “meditation in motion” (Robins et al., 2012) because, like meditation, it involves moment-to-moment changes of attention, self-regulation of attention and orientation towards one's own experiences, self and surroundings. These meditative characteristics of TC should allow for mindfulness training that could positively influence the ability to respond to stimuli in a non-automated and flexible way. Indeed, meditation has been shown to be involved in improving attentional function and cognitive flexibility. Indeed, Mortimer et al. (Mortimer et al., 2012) observed that the TC group increased executive control performance and brain volume, compared to a walking group and a naïve control group. The results of the present study are consistent with previous studies in which mind-body exercise has been observed to be involved in improving both cognitive and motor functions. For example, Lei Cui and colleagues (Cui et al., 2021) observed that the practice of TC resulted in a change in brain functioning that predominantly involved the olfactory cortex, left thalamus, left inferior temporal gyrus, right precuneus and bilateral posterior cingulate gyrus, compared to the control group. Specifically, the authors suggested that TC might promote a functional specialisation of the brain that could be an important predictor of improved cognitive flexibility.

Contrary to previous studies in which gait changes are evaluated through the calculation of space-time parameters (Rucco, Liparoti, & Agosti, 2020), in this study the influence of multimodal and unimodal PE it was investigated through the HR (Roche et al., 2013), which

is a synthetic index which provide information about the smoothness of movement. The higher score of medio-lateral HR in TC practitioners group demonstrate that this type of PE not only affects cognitive functioning but also movement smoothness. The slow and repetitive movements, which involve controlling the position of the centre of mass in relation to the centre of pressure, train the smoothness of movements, which are more harmonious and fluid.

This study has both strengths and limitations. The strengths include the attempt to identify the type of aerobic exercise that might induce better dual task abilities. This information could have important implications for clinical and rehabilitative practice, underlining the need to promote alternative and adapted modalities of exercise as a strategy to maintain or strengthen different aspects of EF. Furthermore, this study leads to reflect more deeply, on the role that PE should play also in educational contexts, in which a promotion of multimodal PE aimed at improving the executive functions could be an effective educational strategy. However, this is a preliminary study and further investigations are needed to confirm the results. Furthermore, in the study only one type of unimodal and multimodal physical exercise was evaluated, to have robust data it could be interesting to compare different unimodal and multimodal exercises. Finally, increasing the sample size could offer the opportunity to highlight the differences between the PE modalities and the control group with greater statistical power.

Conclusions

In conclusion, multimodal exercise appears to positively influence dual task skill. Research should continue to explore this new line of inquiry, as this could aid in the development of physical education programs that can be applied in both clinical and educational settings.

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