**Dual-tasking effects on static and dynamic postural balance performance: a comparison between endurance and team sport athletes**

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**Abstract**

Despite the dual-task paradigm is widely studied in elderly and pathological subjects, few works have investigated those aspects in athletes. Therefore, we aimed to study the effects of a cognitive task on static (SPBC) and dynamic postural balance control (DPBC) comparing endurance (END) and team sports (TP) athletes. Sixteen competitive TP and 19 competitive END took part in the study. SPBC was assessed on a stabilometric platform in single (ST) and dual-task (DT) condition. DPBC was evaluated measuring the anterior-posterior oscillations while standing on a dynamic board both in ST and DT. Results revealed that SPBC decreased in DT condition in TP but not in END. Conversely, no differences in DPBC were detected in both groups comparing ST and DT, except for the END in DT which improved their performance on the dynamic board. The comparison between END and TP showed no differences in static and dynamic postural control in neither of the two conditions. Lastly, we found a significant decrease in cognitive performance among both END and TP when increasing the difficulty of the postural task. In conclusion, TP static postural balance control was negatively affected by the DT in static but not in dynamic conditions. For END, an involvement of an external attentive focus could be the explanation of the improvement in the postural performance during the DT dynamic condition. TP did not show a better postural than the END. Finally, since the human attentive capacity is limited, an increase in the difficulty of the postural task led to a worsening in cognitive performance.

**Introduction**

Postural balance control (PBC) is the act of maintaining (i.e. maintenance of a posture), achieving (i.e. voluntary moving) or restoring (i.e. reacting to external disturbance) a state of balance during any posture or activity (Pollock, Durward, Rowe, & Paul, 2000). In static conditions, postural performance is generally referred to the ability to reduce body sway in ordinary postures as well as the ability to retain body balance in demanding static postures (Paillard & Noé, 2015). In dynamic tasks, postural performance represents the ability to control the body balance during complex movements and challenging postural conditions (e.g. during external mechanical perturbations) in order to prevent falls (Paillard & Noé, 2015). PBC is a multifactorial ability and therefore it is influenced by several intrinsic factors as: age (Ruffieux, Keller, Lauber, & Taube, 2015), anthropometry (Chiari, Rocchi, & Cappello, 2002; Hue et al., 2007), physiological and physiopathological state (Paillard, 2017b; Rinalduzzi et al., 2015), and motor experience (Paillard, 2017a). In sports PBC has been demonstrated to be one of the limiting factors of performance as well as to be related to the risk of injuries (Zemková, 2014). Moreover, regardless of the type of sport, no sport technique is achievable without an efficient body balance (Paillard, 2017a). For instance, high postural skills allow to run in a high economical way (Paillard, 2019) or to better control the ball in the air on one leg in soccer (Paillard, 2017a). Similarly, it has been showed a positive correlation between postural stability and performance in basketball (Perrin, 1991).

For a deeper insight into PBC, the dual-task (DT) paradigm (i.e. the contemporaneous performance of a second task besides the postural one) has been introduced and widely studied in different populations (Woollacott & Shumway-Cook, 2002). The DT paradigm assumes that the central nervous system has limited attentional resources and when more tasks are performed at the same time, they may lead to interference between the two tasks. If processing capacities of the subject are exceeded, a decreased performance in one or both tasks may occur. DT has been extensively adopted in studies with older adults and pathological subjects because of their inability to effectively allocate attention to balance in multi-tasking conditions (Lajoie, Teasdale, Bard, & Fleury, 1993). Surprisingly, only few studies have investigated the DT effects on PBC among athletes. About that, the comparison between team player athletes (TP) and endurance athletes (END) is of interest. The firsts must simultaneously process multiple information while executing at the same time the skills of the game (Gabbett, Wake, & Abernethy, 2011). The seconds must perform only continuous and cyclical repetitions of the same gesture (e.g. running or swimming) for long distances adopting cognitive strategies and focus of attention to increase the quality of the gesture and thus the performance. On this topic, previous investigations showed that runners adopting an associative rather than a dissociative strategy ran faster (K. S. Masters & Ogles, 1998; W. P. Morgan, Johnson, & Morgan, 1977). Moreover, an external focus of attention increased running economy with respect to employing an internal focus of attention (Cona et al., 2015; Schücker, Hagemann, Strauss, & VÖlker, 2009). Therefore, while TP generally experience situations where they must perform more cognitive and/or motor tasks simultaneously (Huang & Mercer, 2001), END concentrated on quality of their gesture to enhance the level of performance , without concurrently perform other cognitive or motor tasks. Due to the intrinsic requirements of the sports described above and to the importance of PBC in both TP and END, in the present study we aimed to compare static and dynamic postural balance control between these two categories of sport. Since TP and END differ for cognitive sport-related demands, we also investigated PBC performance in DT condition. We hypothesized that TP would have a better postural performance compared to END, and that TP would have exhibited a smaller decrease of PBC performance than END when PBC was assessed under DT condition. This because TP are used to face concurrent cognitive and/or motor tasks during trainings and matches.

**Methods**

**Participants**

Nineteen END (age: 28.32±4.59 yrs, height: 1.79±0.06 m, body mass: 70.21±5.97 kg) and 16 TP (age: 23.44±2.49 yrs, height: 1.88±0.09 m, body mass: 82.66±9.6 kg) took part in this study. Among TP, 7 were volleyball players, 4 basketball players, 4 field hockey players, and 1 football player. END included 11 marathon runners, 3 triathletes, and 5 ultra-marathon runners. Both TP and END trained at least 4 times per week. Inclusion criteria were the absence of acute and overuse musculoskeletal injuries, as well as ongoing neurological pathologies, vestibular and hearing disorders. At the time of testing, all the participants were cleared for regular sport practice.

**Protocol**

The tests were performed from April to July 2019 in the nutrition and exercise physiology laboratory of the Department of Biomedical Sciences, University of Padova. All participants were informed about the experimental procedures and signed an informed consent prior testing. Participants performed the tests in a single session. This study was carried out in accordance with the Declaration of Helsinki. The experimental protocol was approved by the Ethics Committee of the Department of Biomedical Sciences.

**Static postural balance assessment**

A bipodalic static postural balance test was performed on a force platform (AMTI BP 400600, AMTI, Watertown, USA) for SPBC assessment. Participants were asked to stand on the platform with the arms relaxed along their sides and to gaze a target placed on a wall at 1 m distance. All trials were performed barefoot, with the heels aligned and the feet forming an angle of 30° (Kapteyn et al., 1983). In DT condition, we employed a counting backwards task as in previous works (Swanenburg, de Bruin, Uebelhart, & Mulder, 2010). Participants were provided a starting number above 200 and were asked to count backwards by 7 aloud as accurately as possible for the duration of the whole standing trial. Two trials of 50s for each condition were recorded at a sampling rate of 100Hz. The last 40s were considered for the analysis. The SPBC performance was assessed throughout the area of the confidence ellipse (cm2) and the sway path mean velocity (cm/sec). The cognitive performance was evaluated with the number of correct subtractions given. For all the parameters the mean between the two trials was computed and considered for the analysis.

**Dynamic postural balance assessment**

For the assessment of the DPBC an unstable board was employed. The board enabled the oscillations only around one single axis. Two reflective markers were placed on the right edge of the board. A six-camera motion capture system (OptiTrack, NaturalPoint®, Corvallis, OR, USA) was employed to record the three-dimensional (3D) coordinates of the 2 markers and thus the motion of the board. The sampling rate was set at 100Hz. Participants stood on the board aligning the mid-point of the platform with the mid-point of each foot (measured as half the distance between the medial malleolus and the basis of the first metatarsus), thus allowing anterior-posterior oscillations. Participants were instructed to maintain the board parallel to the floor as much as possible without moving the feet from their starting position. Before the data collection, the participants underwent a 5 min familiarization session with the board. Then, they performed two trials of 45s for each condition (i.e. ST and DT). The last 40s of each trial were considered for the analysis. The software Smart Analyzer (BTS bioengineering, Milano, Italy) and Smart Tracker (BTS, bioengineering, Milano, Italy) were used in the post-processing analysis to compute the angular oscillations of the board over the duration of the trial. The DPBC performance was assessed considering the following objective parameters: (1) the integral of the angle-time curve (Full Balance, FB), (2) the time each athlete was able to stay between +4° and -4° (Fine Balance, FiB) and (3) between +8° and -8° (Gross Balance, GB). Briefly, the smaller is the FB, the better is the dynamic postural performance; whilst for the FiB and GB the higher is the value, the better is the dynamic postural performance. The cognitive performance was evaluated as the number of correct subtractions given. As for the SPBC, the mean of the values collected in the 2 trials was used for the analysis.

**Statistical analysis**

A Two-way ANOVA for repeated measurements was carried out to detect a possible effect of the type of sport (i.e. TP or END) or of the task condition (i.e. ST or DT) on the postural balance performance. Differences were located by the Bonferroni post hoc test. A second two-way ANOVA and Bonferroni post hoc test were performed to investigate the influence of the type of sport (i.e. TP or END) or of the postural condition (i.e. SPBC and DPBC) on the cognitive performance (i.e the number of correct subtractions given). The level of significance was set at p < 0.05. Data analysis was performed using GraphPad Prism software (version 8.00, GraphPad Software, San Diego California USA).

**Results**

In the SPBC assessment, the area of the confidence ellipse was significantly influenced by the task condition (p < 0.05; 3.9% of total variation) with a better performance in the ST condition. A tendency to the statistical significance was found for the effect of the type of sport practiced (p = 0.063; 6.7% of total variation) with an overall better performance of END compared to TP. Bonferroni post-hoc analysis showed an increment of the area of the confidence ellipse among TP in the DT condition compared to the ST condition (2.89±2.65cm2 vs 1.68±0.89cm2; p < 0.001) while END highlighted no differences comparing DT and ST conditions (1.49±0.85cm2 vs 1.49±0.69cm2). Moreover, END showed in the DT condition a smaller area of the confidence ellipse than TP (1.49±0.85cm2 vs 2.89±2.65cm2; p < 0.05). Regarding the sway path mean velocity a main effect of the type of sport (p < 0.05; 7.9% of total variation) and of the task condition (p < 0.001; 13.9% of total variation) was detected. As per the area of the confidence ellipse, Bonferroni post hoc analysis showed an increase of the sway path mean velocity in the DT condition for TP (3.07±0.47cm/s vs 2.69±0.23cm/s; p < 0.001), but not for END (3.19±0.4cm/s vs 2.99±0.24cm/s). Conversely, a smaller sway path mean velocity was detected for TP compared to END in the ST condition (2.69±0.23cm/s vs 2.99±0.24cm/s; p < 0.001) but not in DT (3.07±0.47 vs 3.19±0.4)

Conversely, in the DPBC assessment no main effects or interactions were detected for all the parameters considered. However, a tendency to the statistical significance was detected for the task condition in the FB (p = 0.088; 1.57% of total variation) and FiB (p = 0.072; 1.83% of total variation). Post hoc analysis detected a statistically significant decrease of the FB (p < 0.05) and an increase of GB (p < 0.05) and FiB (p < 0.05) in DT for END.

Finally, regarding the cognitive score only a main effect of postural condition (p < 0.001) was observed. Post hoc analysis showed a significantly lower cognitive score in dynamic condition compared to static condition for both END (p < 0.001) and TP (p < 0.05).

**Discussion**

In the present study we investigated the differences in SPBC and DPBC performance between TP and END. The analysis was performed both in ST and DT condition. The main finding is that END and TP showed a different behavior in coping SPBC and DPBC both in ST and DT condition. Considering SPBC in ST condition END showed a smaller area of the confidence ellipse (-11.3%) and a higher sway path velocity (+11.1%) compared to TP. We can assume that in this condition END showed a better postural balance control (i.e. smaller area of the confidence ellipse) even if with a less efficiency (i.e. higher velocity of the COP) than TP. Moreover, TP showed a worse SPBC in the DT condition while END maintained their performance unchanged. These results already refused our initial hypothesis, that was mainly based on two assumptions. The first was that DT condition has been demonstrated to simultaneously increase the complexity of the physiological and behavioral system leading to a cognitive-motor interference (Ghai, Ghai, & O Effenberg, 2017; Woollacott & Shumway-Cook, 2002) that could have worsened the SPBC in both END and TP and not only in TP. The second was linked to the requirements of team sports where players are used to simultaneously process multiple information while executing at the same time the skills of the game (Gabbett et al., 2011). Therefore, according to this assumption, we expected in DT condition a less worsening of the SPBC for TP rather than for END, due to their practice in coping multiple information. However, it must be considered that SPBC mainly occurs at brainstem-spinal levels due to its extremely predictable context (Lajoie et al., 1993). Conversely, TP always perform dynamic tasks in a less predictable context involving the cognitive processes of PBC and thus, adopting a prevalent supra-spinal postural strategy to achieve their goal-directed movements (Lajoie et al., 1993; Takakusaki, Takahashi, Obara, & Chiba, 2017). On the other hand, the unaltered SPBC performance of END in the DT condition could be explained considering these athletes usually employed an external focus to enhance their performance. Indeed, among END, counting backward aloud represented an external focus that could have influenced SPBC according to the theory of reinvestment (R. Masters & Maxwell, 2008). In support to this content, it has already been shown how an external focus of attention may improve performance measures related to aerobic performance, such as speed (LaCaille, Masters, & Heath, 2004) and duration of the endurance task (William P Morgan, Horstman, Cymerman, & Stokes, 1983), throughout an improvement in running economy and kinematics (Hill, Schücker, Hagemann, & Strauß, 2017; Schücker & Parrington, 2019). In compliance with the theory of reinvestment, relatively automated motor processes (i.e. SPBC) could be impaired if they are run using a declarative memory (which requires much more attention) rather than a procedural memory (which is more automated). Therefore, the external focus (i.e. counting backward aloud) could have reduced the conscious control of SPBC, in favor of those automated control mechanisms that effectively rule SPBC (Takakusaki et al., 2017).

Looking the results of DPBC our initial hypothesis of a better performance in the TP with respect to END was also refused. About that, it has to be considered that in DPBC there is a prevalence of the supra-spinal postural strategy (Lajoie et al., 1993) with a higher involvement of the cognitive process of PBC (Takakusaki et al., 2017) and that TP usually perform voluntary tasks in DT condition during matches and training. Therefore, we can speculate their DPBC remained unchanged when the concurrent cognitive task was introduced just because the dynamic experimental condition proposed was much closer than the static one to the on-court context. Conversely, END showed during DPBC a better performance in the DT condition. As per the SPBC, this could be explained by their consolidated habit employing an external focus during competitions to improve the performance (Hill et al., 2017; LaCaille et al., 2004; Schücker & Parrington, 2019). Indeed, counting backward aloud was an external focus among END which could have contribute improving the DPBC performance.

Finally, results of the cognitive performance showed no differences between TP and END, with a decrement of the correct subtractions given in the dynamic test on the oscillating board compared to the static test. The capacity sharing model (Pashler, 1994) can account this worsening. This model assumes that the mental processing capacity is finite and must be shared among tasks. Therefore, since the difficult of the cognitive task was the same both in static and dynamic condition as well as the total processing capacity of the participants involved, we can assume that the dynamic motor task absorbed more processing capacity than the static motor task. Consequently, less processing capacity was available for the cognitive task leading to a lower number of correct subtractions given during the dynamic test.

In conclusion, some limitations have to be acknowledged. Firstly, it was not possible to match TP and END for age and anthropometry because, due to the requirements of the disciplines, TP are on average younger, higher and heavier than END. However, our approach guaranteed the ecological validity of our study. Secondly, the standardization of the cognitive task did not allow to find a task that was equally usual for both TP and END. In fact, counting backward aloud was closer to what the END experienced in their disciplines when adopting external focus strategies rather than to what the TP experienced on court. Indeed, in TP concurrent cognitive tasks are more sport-oriented and aimed at the success of a game scheme.

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