

BALANCE PERFORMANCE AND RECOVERY AFTER EXERCISE WITH WATER INTAKE, SPORT DRINK INTAKE AND NO FLUID

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The objective of the present study was to determine the effects of exercise with water intake, sport drink intake and no fluid on balance performance and recovery. Seventeen physically active men (age, 22.29 ± 1.61 years; height, 176.24 ± 5.18 cm; weight, 69.47 ± 9.20 kg) volunteered to take part in this study. The Biodex Balance System was used to evaluate balance performance and Overall Stability Index (OSI) scores were used to assess balance performance. The exercise protocol consisted of a 1-hour exercise session at 75% and 85% of maximal heart rate. The recovery period was 20 minutes of rest without fluid intake. In all experiment conditions, balance tests were applied three times as pretest, posttest and recovery. In each one of the three experimental conditions, balance tests were consecutively performed with eyes open and eyes closed. All the measurements and exercise protocols were performed in the morning (between 9 AM and 12 PM), in a specially designed and equipped room, with room temperature at 21–24°C. Repeated-measures ANOVA was used to examine all the conditions. OSI post-exercise was significantly higher than pre-exercise ($p < 0.01$) and recovery ($p < 0.05$) for exercise with no fluid and eyes open. There was a non-significant difference in OSI between pre-exercise and recovery. No significant differences in OSI for exercise with sport drink intake and water intake were observed among pre-exercise, post-exercise and recovery. The results of this study show that balance performance decreases after prolonged exercise without fluid intake, and that fluid ingested during sport activities could prevent the decrease in balance performance. [*J Exerc Sci Fit* • Vol 8 • No 2 • 105–112 • 2010]

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Introduction

Postural control or balance can be described statically as the ability to maintain a base of support with minimal movement, and dynamically as the ability to perform a task while maintaining upright stance (Guskiewicz 2001). The maintenance of posture is essential for sports performance and normal daily activities. The maintenance of upright stability is achieved by using orientation information derived from three independent sensory sources: somatosensory, vestibular and visual inputs (Lepers et al. 1997). Fatigue or injury may affect the sensorimotor system both directly and indirectly, hampering

neuromuscular control and leading to functional instability (Tripp et al. 2007). Altered somatosensory input due to fatigue could result in deficits in neuromuscular control as represented through deficits in postural control (Gribble & Hertel 2004). Muscle fatigue may impair the proprioceptive and kinesthetic properties of joints by increasing the threshold of muscle spindle discharge, disrupting afferent feedback, and subsequently altering conscious joint awareness (Balestra et al. 1992).

On the other hand, while performing physical activity, individuals are exposed to various factors that induce sweat loss. These factors are exercise intensity and duration, environmental conditions, and the type of clothing/equipment worn. Physical exercise can cause high sweat rates and substantial water and electrolyte loss (Sawka et al. 2007). Dehydration due to exercise is characterized as a consequence of body fluid loss that exceeds fluid intake (American College of Sports Medicine 2000). The severity of acute or subacute dehydration



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is defined by the percentage of body weight loss (Phillips et al. 1984). Dehydration of 1–2% of body weight begins to compromise physiologic function and influence performance negatively (Casa et al. 2000). Dehydration of greater than 3% of body weight further disturbs physiologic function and increases an athlete's risk of developing an exertional heat illness (Casa et al. 2000). Dehydration can bring about an increase in heart rate, core body temperature and oxygen consumption (Barr 1999).

When solid food can be ingested, water alone is enough to rehydrate. But there are situations in which solid food cannot be ingested or should be avoided. In such cases, it is necessary to add electrolytes to the rehydration drink (Maughan & Shirreffs 1997). Ingestion during exercise aims to replace fluid loss and to maintain blood glucose levels (American College of Sports Medicine 2000). During prolonged exercise, the inclusion of electrolytes in consumed fluids may prevent dehydration. Again, rehydration drinks decrease the negative effects of fluid loss on cardiovascular function and exercise performance (Ostojic & Mazic 2002; Montain & Coyle 1992). The volume of sweat loss in exercise is lower than the volume of body fluid loss because of obligatory urine loss. Therefore, the delectability of the beverage is important (Maughan & Shirreffs 1997).

Dehydration may weaken balance performance (McKinney et al. 2005). There has been some investigation into the effects of exercise with and without hydration on postural control. Patel et al. (2007) found that there were no observable differences in the Sensory Organization Test scores between the euhydrated and dehydrated conditions. However, Derave et al. (1998) suggested that fluid replacement during prolonged exercise can improve post-exercise postural stability. Furthermore, Gauchard et al. (2002) reported that dehydration after exercise altered posture, whereas hydration during exercise allowed retainment of good balance control.

Theoretically, prolonged exercise may cause defects in balance performance. So the first aim of this study was to determine if fluid intake during exercise affects the decrease that may occur in balance performance. It is hypothesized that defects in balance performance may be decreased by fluid intake during exercise. The second aim of this study was to determine if water intake (WI) or sport drink intake (SDI) during exercise affects balance performance. The third aim was to examine the effects of exercise with WI, SDI, or no fluid intake (NF) on balance recovery.

Methods

Subjects

Seventeen men, who regularly practice physical and sporting activities, from the College of Physical Education and Sport (age, 22.29 ± 1.61 years; height, 176.24 ± 5.18 cm; weight, 69.47 ± 9.20 kg) volunteered as subjects. They did not have any diseases of the central nervous system, and had not suffered any orthopedic disorder either of the trunk or the lower limbs in the previous year. None of the subjects had a history of balance training. Before beginning the study, all subjects were informed about the potential risks and benefits, and signed a written informed consent form. The study protocol was approved by the ethics committee of the university.

Test procedure

In this study, a repeated-measures design to assess the subjects under three conditions (NF, SDI, WI) was used. First, the exercise protocol for the NF condition was performed. At least 3 days after the NF condition, exercise protocols for the SDI or WI conditions were randomly conducted with at least 3 days between the two conditions.

In each experimental condition, before and after the exercise protocol and after the recovery period, each subject emptied their bladder and was weighed in the nude on a weighing scale. In the NF condition, the exercise protocol was performed without any fluid intake. The fluid volume was calculated from their body weight loss when the NF condition trial was finished. Each subject's hydration status was assessed by determining body weight before and after the exercise sessions (Casa et al. 2000). The decline in body weight at the end of the exercise was denoted as the fluid volume. During the exercise protocols under the SDI and WI conditions, the fluid volume was divided into equal portions and ingested at 5-minute intervals (Gauchard et al. 2002). The fluid volume was ingested as water in the WI condition and as an 8% carbohydrate-electrolyte sports drink (POWERADE; Coca-Cola Co., Atlanta, GA, USA) in the SDI condition. Subjects were instructed to refrain from alcohol consumption and strenuous exercise the day before each experiment. Participants arrived at the laboratory in the morning of each test day after they had eaten a standard breakfast. All the measurements and exercise protocols were performed in the morning (between 9 AM and 12 PM), in a specially designed and equipped room, with room temperature $21\text{--}24^\circ\text{C}$.

Postural stability

The Biodex Balance System (Biodex Medical Systems Inc., Shirley, NY, USA) was used to evaluate balance performance (Figure 1). This system consists of a circular movable platform interfaced with computer software that enables the device to perform objective measurements of stability indices (Salavati et al. 2007). Resistance levels of the Biodex Balance System range from 12 (most stable) to 1 (least stable), with 1 representing the greatest instability. The Overall Stability Index (OSI) score is believed to be the best indicator of the overall ability of a subject to balance on the platform (Testerman & Vander Griend 1999). The higher the OSI score, the poorer the balance performance (Costa et al. 2009).

Balance tests were conducted using the one-leg stand test with eyes open (EO) and eyes closed (EC). The resistance level used was set at level 3 in EO and at static level in EC. During balance tests, subjects took off their shoes and socks. Balance tests were performed on the dominant foot which subjects reported they used to kick a ball. To assess the foot position coordinates and establish the subjects' ideal foot positioning for testing, the stability platform was unlocked to allow motion. Participants were instructed to adjust the position of the supporting foot until they found a position where they were able to maintain platform stability. At this point, they were allowed to look at the instrument panel to adjust their stability. The platform was then locked and the subject's foot position was recorded by the software. Foot position coordinates were constant throughout the test sessions.

Subjects were allowed three practice trials before pre-exercise balance measurements in the NF, SDI and WI conditions. Subjects were instructed to maintain



Fig. 1 Biodex Balance System.

single leg stance on the platform with both arms folded across their chest. The unsupported limb was held in a position of hip neutral extension with partial abduction and 90° knee flexion so as not to touch the test limb. They were instructed to look straight ahead at a point on the wall approximately 1 meter away at eye level during the tests. During testing, the instrument panel was covered to prevent participants from obtaining performance visual feedback from the BSS. Each balance test lasted 20 seconds and was performed for EO and EC separately.

The reliability of OSI (EO and EC conditions) was determined by the intraclass correlation coefficient (ICC). The ICC values were 0.84 for EO (level 3) and 0.89 for EC (static level). In previous studies, the ICCs for OSI ranged from 0.60 (level 8) to 0.95 (level 2) in healthy subjects (Pincivero et al. 1995), and from 0.77 to 0.99 (level 7 and EC) in healthy male college students (Salavati et al. 2007).

Exercise and recovery protocol

The exercise protocol was conducted on a 0% grade treadmill with at least 3 days of recuperation between conditions (NF, SDI and WI). Subjects were asked to refrain from performing fatiguing exercise for at least 24 hours prior to testing. The exercise protocol consisted of a 1-hour exercise session at 75–85% of their Karvonen maximal heart rate (Karvonen et al. 1957). Heart rate and rating of perceived exertion (RPE) as measured on a 15-point Borg scale (6–20) (Borg 1970) were monitored. Heart rate, RPE and running speeds were recorded at the beginning of the exercise protocol and at 5-minute intervals. The balance tests were repeated as soon as the exercise protocol was finished. Then, subjects emptied their bladder, were dried and weighed in the nude. This was followed by a recovery period of 20 minutes of rest without fluid intake. The balance tests were conducted again after the recovery period.

Data analyses

Descriptive analysis consisted of means and standard deviations for the demographics of all subjects and means and standard deviations for pre-exercise, post-exercise and recovery data for the OSI. General linear model repeated-measures ANOVA was performed for every condition (NF, SDI, WI) and time (pre-exercise, post-exercise, recovery). Multivariate and within-subject effect tests were performed in accordance with variance-covariance structure constancy. Bonferroni *post hoc* analysis was done for time if there was a significant difference. Data were analyzed using SPSS version 16.0

(SPSS Inc., Chicago, IL, USA) for Windows. The α level was set at 0.05 for all analyses.

Results

Table 1 shows the body weight, total body weight loss and percent of body weight loss after exercise. Body weight loss was 1.48 ± 0.26 kg (2.17%) after exercise with NF. In the NF condition, there were significant differences ($p < 0.05$) in the body weight of subjects pre-exercise, post-exercise and after recovery ($F = 806.9$); body weight pre-exercise was different from that post-exercise and after recovery ($p < 0.05$). There was no statistically significant difference in the decline in body weight between post-exercise and recovery. No significant differences were found in body weight pre-exercise, post-exercise and after recovery in the SDI condition ($F = 1.190$) and WI condition ($F = 0.960$). With regard to pre-exercise body weight, there were no significant differences among the three conditions of NF, SDI and WI ($F = 1.162$).

Table 2 shows the heart rate, running speed and RPE during the experimental trials. Heart rate was not significantly different between experimental conditions ($F = 2.871$). The means and comparisons for pre-exercise, post-exercise and recovery measurements of OSI are presented in Table 3. Figure 2 shows the OSI for the experimental trials in the EO and EC conditions.

EO condition

Significant differences ($p < 0.05$) were found in the OSI for exercise with NF among pre-exercise, post-exercise and recovery ($F = 22.67$). The OSI post-exercise was

significantly higher than pre-exercise and recovery (both $p < 0.05$). But there was no significant difference in OSI between pre-exercise and recovery. No differences in OSI for exercise with SDI ($F = 1.86$) and WI ($F = 0.617$) were observed among pre-exercise, post-exercise and recovery.

EC condition

Exercise with NF ($F = 6.24$) resulted in significant differences ($p < 0.05$) in OSI. Post-exercise scores were significantly higher than pre-exercise scores ($p < 0.05$). Recovery balance test results were not significantly different between pre-exercise and post-exercise. No significant differences were found in OSI for exercise with SDI among pre-exercise, post-exercise and recovery ($F = 0.374$). Significant differences ($p < 0.05$) were found in OSI for exercise with WI among pre-exercise, post-exercise and recovery ($F = 5.40$). A significant difference was identified between post-exercise and recovery

Table 3. Comparison of Overall Stability Index trials in the eyes open (EO) and eyes closed (EC) conditions*

	Pre-exercise	Post-exercise	Recovery
EO			
NF	3.01 ± 1.07	$4.13 \pm 1.63^{\dagger\ddagger}$	$2.93 \pm 1.06^{\S}$
SDI	$3.02 \pm 1.04^{\parallel}$	$3.43 \pm 1.06^{\parallel}$	2.98 ± 0.98
WI	2.46 ± 0.65	2.71 ± 0.69	2.65 ± 1.10
EC			
NF	3.42 ± 0.68	$4.14 \pm 1.01^{\dagger}$	$3.91 \pm 0.86^{\parallel}$
SDI	3.51 ± 1.20	3.76 ± 1.25	3.54 ± 1.09
WI	3.09 ± 1.23	3.59 ± 1.02	$2.89 \pm 0.98^{\S}$

*Data presented as mean \pm standard deviation; $^{\dagger}p < 0.05$ vs. pre-exercise; $^{\ddagger}p < 0.05$ vs. SDI and WI; $^{\S}p < 0.05$ vs. post-exercise; $^{\parallel}p < 0.05$ vs. WI. NF=no fluid intake; SDI=sport drink intake; WI=water intake.

Table 1. Subjects' body weight, total body weight loss and percent body weight loss after exercise*

	NF	SDI	WI
Body weight pre-exercise (kg)	69.47 ± 9.20	69.35 ± 9.17	69.33 ± 9.15
Body weight post-exercise (kg)	$67.98 \pm 8.91^{\dagger}$	69.52 ± 9.11	69.45 ± 9.22
Body weight after recovery (kg)	$67.95 \pm 9.17^{\dagger}$	69.42 ± 9.14	69.37 ± 9.17
Body weight loss post-exercise (kg)	1.48 ± 0.26	0.16 ± 0.42	0.12 ± 0.71
Percent body weight loss	2.17 ± 0.32	0.23 ± 0.64	0.16 ± 0.78

*Data presented as mean \pm standard deviation; $^{\dagger}p < 0.05$ vs. pre-exercise. NF=no fluid intake; SDI=sport drink intake; WI=water intake.

Table 2. Subjects' heart rate (HR), running speed and rating of perceived exertion (RPE)*

	NF	SDI	WI	F	p
HR (beats \cdot min $^{-1}$)	163.48 ± 5.35	163.26 ± 7.35	160.84 ± 5.43	2.871	0.073
Speed (km \cdot hr $^{-1}$)	9.92 ± 1.24	10.05 ± 1.28	10.24 ± 1.17	1.852	0.176
RPE scores	10.35 ± 2.84	9.93 ± 2.95	9.70 ± 2.43	3.103	0.103

*Data presented as mean \pm standard deviation. NF=no fluid intake; SDI=sport drink intake; WI=water intake.

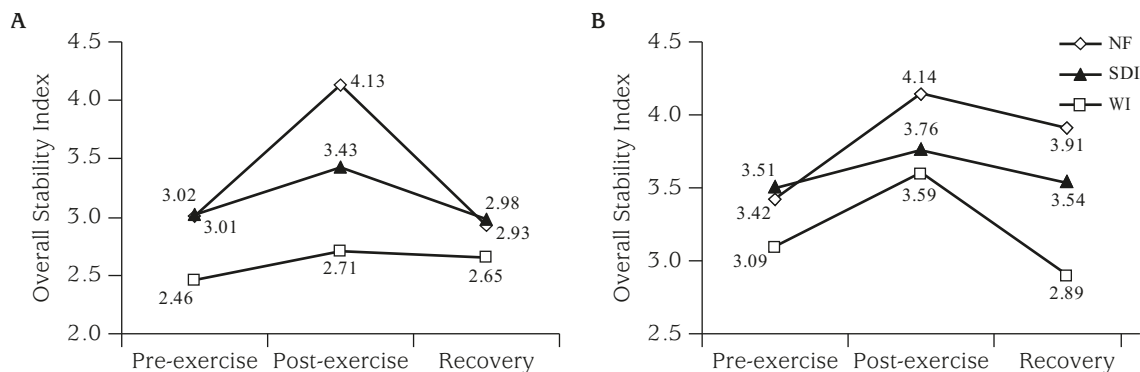


Fig. 2 Overall Stability Index in the experimental trials: (A) eyes open; (B) eyes closed. NF=no fluid intake; SDI=sport drink intake; WI=water intake.

($p < 0.05$). Pre-exercise test results were not significantly different from those of post-exercise and recovery.

Between pre-exercise measurements

A significant difference ($p < 0.05$) was identified in OSI between pre-exercise measurements in the EO condition ($F = 3.436$). OSI with WI was significantly lower than with SDI ($p < 0.05$). OSI with NF was no different from that with WI and SDI. On the other hand, in the EC condition, no significant difference was found in OSI between pre-exercise measurements ($F = 1.590$).

Between post-exercise measurements

A significant difference ($p < 0.05$) was identified in OSI between post-exercise measurements in the EO condition ($F = 10.887$). OSI with NF was significantly higher than with SDI and WI ($p < 0.05$). OSI with SDI was significantly higher than with WI ($p < 0.05$). No significant difference was found in OSI between post-exercise measurements in the EC condition ($F = 2.298$).

Between recovery measurements

In the EO condition, no significant difference was found in OSI between recovery measurements ($F = 0.925$). A significant difference ($p < 0.05$) was identified between recovery measurements in the EC condition ($F = 10.098$). OSI with NF was significantly higher than with WI ($p < 0.05$). Balance performance with SDI was not significantly different from that with NF and WI.

Discussion

Muscle fatigue is connected to a decline in tension capacity or force output after repeated muscle contraction (Powers & Howley 1990) and causes a decrease on

postural stability (Lepers et al. 1997; Nardone et al. 1997; Alderton & Moritz 1996). According to our study's findings, balance performance decreased in the EO and EC conditions depending on the negative effects of fatigue at the end of NF exercise. No difference was found between post-exercise and recovery balance performance in the WI and SDI exercise groups. This may indicate that fluid taken during the 1-hour exercise may prevent the decrease in balance performance. Similarly, Derave et al. (1998) suggested that water and carbohydrate supplementation during prolonged exercise may promote postural performance during activities. Also, WI or SDI during exercise did not affect this result. As for the recovery period, balance performance returned to pre-exercise levels. Only in WI exercise in the EC condition did recovery balance performance significantly increase compared to post-exercise. It is thought that this may have resulted from the learning and practice effects of the balance test.

Gauchard et al. (2002) applied 45 minutes of exercise twice at a power corresponding to approximately 60% of individual $\dot{V}O_{2max}$, first without fluid intake and then with WI. It was reported that post-exercise dehydration affected postural performance negatively and hydration performed during exercise contributed to getting postural performance again.

Derave et al. (1998) applied a 2-hour exercise protocol twice on different days. Subjects did not ingest fluid in the first experimental trial of this protocol. In the second experimental trial, sports drink, equivalent to the body weight lost in the first exercise, was given at 15-minute intervals. Posturography measurements were conducted before exercise and 20 minutes after the end of the exercise. They concluded that fluid intake during prolonged exercise may improve post-exercise stability. It has been reported that balance recovery

occurs in 20 minutes (Gribble & Hertel 2004; Susco et al. 2004; Wilkins et al. 2004; Lepers et al. 1997; Nardone et al. 1997). Susco et al. (2004) reported that exertion adversely affected balance at the end of exercise and balance recovery occurred within 20 minutes after exercise ceased. Different from Derave et al. (1998), balance measurements were taken immediately after the end of exercise and 20 minutes after the end of exercise in our study. So balance performance immediately after exercise with and without fluid ingestion may be observed much better in our study.

In another study, an exercise protocol was performed at a speed corresponding to 60–75% of maximal heart rate until body weight loss rate reached 3% (McKinney et al. 2005). To avoid the effects of fatigue, postural sway measurements were repeated following a 20-minute recovery period after exercise. It was reported that the dehydration created with exercise decreased balance performance after the 20-minute recovery period. In contrast with the results of McKinney et al. (2005) and Derave et al. (1998), the results of our study indicate that balance performance decreases immediately after exercise without fluid intake and balance recovery occurs 20 minutes later. In addition, balance performance did not change during the exercise and after both exercises in which fluid was taken.

Patel et al. (2007) studied postural sway in dehydration and normal hydration conditions. No difference was reported for the visual and vestibular rates in the dehydration condition. Also, it was reported that Balance Error Scoring System scores did not show an increase after dehydration.

In the studies that support the results of our study, it was reported that exercise negatively affects postural sway performance (Springer & Pincivero 2009; Khanna et al. 2008; Gribble & Hertel 2004; Susco et al. 2004; Wilkins et al. 2004; Ageberg et al. 2003; Pendergrass et al. 2003; Yaggie & McGregor 2002; Nardone et al. 1997). Nardone et al. (1997) reported a significant increase in body sway measured with EO and EC after fatiguing exercise on the treadmill. A decrease in maintaining balance ability was observed after short-duration submaximal bicycle exercise (Ageberg et al. 2003). Khanna et al. (2008), Susco et al. (2004) and Wilkins et al. (2004) noted that Balance Error Scoring System performance decreased significantly after fatiguing exercise.

In research on postural sway, it was pointed out that balance recovery occurs within 20 minutes after fatiguing exercise (Khanna et al. 2008; Susco et al. 2004; Yaggie & McGregor 2002). Nardone et al. (1997)

reported that all effects of exercise were of short duration and seen immediately after exercise and vanish by about 15 minutes after the end of exercise. Khanna et al. (2008) reported that balance recovery occurred in 15 minutes after aerobic exercise, in 10 minutes after anaerobic exercise and in 20 minutes after mixed exercise.

Before exercise with EO, balance performance was significantly higher with WI than NF. This difference may result from learning-practice effect. While three experimental groups were significantly different from each other in the EO condition after exercise, no difference was found among the groups in the EC condition. If balance performance before exercise is also taken into account, it may be thought that balance performance decreases after exercise performed without fluid intake. In parallel with this result, Gauchard et al. (2002) reported that the balance performance of subjects with fluid intake was higher than that of subjects who did not ingest fluid at the end of 45 minutes of exercise.

It is difficult to explain with current data why post-exercise balance performance did not differ in the EC condition compared with the results in the EO condition. But when visual inputs are limited, the somatosensory system may increase its effect on maintaining balance performance. Patel et al. (2007) reported that postural sway performance in dehydration conditions in vestibular domain significantly increased when compared to the normal hydration condition. They stated that it was difficult to explain this finding, but exercise would improve lower-extremity somatosensory integrity as a result of muscle activity.

With regard to balance recovery performance, while no difference was seen in the EO condition, it was significantly higher with WI than with NF in the EC condition. If pre-exercise WI performance is examined, it may be thought that this finding results from learning-practice effect. These results show that after exercise, balance recovers within 20 minutes independently of fluid intake (Khanna et al. 2008; Susco et al. 2004; Yaggie & McGregor 2002; Nardone et al. 1997).

In repeated balance measurements, the learning-practice effect has been found in many studies (Valovich et al. 2003; Mancuso et al. 2002; Hansen et al. 2000; Nordahl et al. 2000). It has been determined that the shorter the time between postural sway measurements, the more the learning is (Nordahl et al. 2000). Nardone et al. (1997) reported that body sway measured in the EC condition after non-fatiguing exercise was not significantly different from that pre-exercise. Sway path

decreased significantly at the end of non-fatiguing exercise. This unexpected decrease in sway values could be explained by the learning effect because of the repetition of the balance tests.

A limitation of our study is that the application of the NF condition was conducted first and then the other conditions were performed. This may have caused a practice effect. Another limitation is that the EO condition was applied first, followed by EC, during the balance measurements. Since time passed during measurement in the EO condition, it may have allowed short-term balance recovery and a practice effect.

In conclusion, according to the data in the present study, balance performance decreases after prolonged exercise without fluid intake, and fluid ingested during sport activities could prevent such a decrease in balance performance. Hydration helps to keep an accurate muscular efficacy during exercise. Fatiguing exercise decays postural regulation due to lower muscular efficiency and poor sensory information sensitivity (Gauchard et al. 2002). Our results also show that WI or SDI during exercise has the same effect in terms of balance performance. In addition, we found that balance performance returns to baseline levels within 20 minutes of rest after prolonged exercise independently of fluid intake. Trainers and coaches must carefully observe hydration levels during physical activity and take into account the fact that fatiguing exercise decreases balance performance while evaluating postural sway.

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