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Original Article

Aspects of balance ability in Swimming

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Abstract

Purpose. The aim of this research was to identify de level of the balance skills of the swimmers (as case studies) by testing the static and dynamic balance as a sensorial response to visual stimuli.

Methodology. The study regarded seven subjects (three males and four female) approached as case studies, performance swimmers, medalists at National Championships The work took place at the Human Performance Research Center laboratory and we used as testing tool the Balance Miniboard platform manufactured by Sensamove. The subjects were tested for static and dynamic balance having visual feedback in real time by looking at the notebook's display. Each test lasts 30 seconds, while the subject has to stay as balanced as possible; to move the body mass from left to right, front and back.

Results and discussions. Regarding the static balance ability, the subjects presented low values of the average deviations from the reference point (0) for all four measuring points, among them, only the S_4 subject recording the highest values (1,830 forward and -2,79^0 towards backwards, -2,34^0 to the left and 2,53^0 to the right). The performances obtained in the front-to-back dynamic balance measurement showed the highest values, three of the subjects achieving percentages over 90% (S_1 - 94%, S_2 - 96% and S_7 - 96%).

Conclusions. The research has highlighted that balance is a basic element of swim training that can provide details of neuromuscular control identified by assessing the dynamics of postural oscillations in the frontal and sagital plane, the information that can be obtained representing objective indices regarding the ability to sensory structural reorganization under different conditions of motor tasks.

Key Words: motor control, proprioception, sensory response, visual feedback.

Introduction

Everyone knows that the balance is a biological system that enables us to know where our bodies are in the environment and to maintain a desired position. Normal balance depends on information from the inner ear, other senses (such as sight and touch) and muscle movement. According to Tsigilis *et.al.* 2001, balance is considered an essential component of almost every motor performance task. Its function is regulated by the central nervous system based on the afferent visual, tactile, and proprioceptive impulses, as well as on information from the vestibular system (McLeod & Hansen, 1989; Boswell, 1993; Ageberg, Zatterstrom, & Moritz, 1998; Kmzey & Armstrong, 1998). There are two types of balance, static and dynamic. Static balance refers to maintenance of certain posture while stationary, and dynamic balance refers to maintenance equilibrium during rapid changes of the individual's kinetic condition. Various tests have been constructed to measure static and dynamic balance. Research evidence has indicated no correlation between the two types of balance (Travis, 1945; Drowatzky & Zuccato, 1967; Sanborn & Wyrick, 1969). This finding is also evident when assessing balance after stimulation of the vestibular system (Tsigdis, Douda, Mertzanidou, & Sofiads, 1998).

In 2015 Heinbaugh *et.al.* were talking about two categories of balance, many assessments have been developed and applied to athletes (Hrysomallis, 2007, 2011). Athletes can be generally categorized by age (youth vs. adult), level of competition (recreational vs. professional and varsity vs. club vs. intramural), and sports events (Butler, Southers, Gorman, Kiesel, & Plisky, 2012; Theiss *et al.*, 2014). Recreational athletes are representative of the general physically active population, thus, have been commonly studied (Dai *et.al.*, 2015; Munro & Herrington, 2010; Schloemer, Cotter, Jamison, & Chaudhari, 2013). Previously, investigators have demonstrated that decreased balance performance is associated with increased risks for sports injuries (Hrysomallis, 2007; McGuine, Greene, Best, & Leverson, 2000; Paterno *et.al.*, 2010; Plisky, Rauh, Kaminski & Underwood, 2006; Tropp, Ekstrand & Gillquist, 1984). In addition, balance training has been shown to decrease the risk factors and rates of sports injuries (Hrysomallis, 2007; McGuine & Keene, 2006; Verhagen *et.al.,* 2004), and help to enhance sports performance (Hrysomallis, 2011). Understanding the contributing factors to balance performance in recreational athletes can provide implications on injury prevention and performance training.

The ability to maintain one's balance under various circumstances is recognized as one of the basic motor skills. It is an essential factor in movements made in numerous sports and physical education activities. The optimum balance for each sport performance results from the use of the stance best adapted to the particular skills involved in that sport. Hence, balance is an important factor in batting, throwing, and fielding in softball;

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forehand and backhand drives in tennis; all strokes in golf; line play in football; dribbling and shooting in basketball; building pyramids in gymnastics, etc (Elmer *et.al.*, 2013).

Davlin appears in 2004 with a study that states that: if athletes differ from non-athletes only with regards to specific skills required by their particular sport, as suggested by Kioumourtzoglou, *et.al.* (1997), then it would therefore be logical that gymnasts, who train to improve their ability to maintain balance as well as recover and regain balance in multiple situations, would outperform the other athletes and non-athletes in this study. This supports Singer's findings (1970) in which athletes who practiced balance skids similar to the one tested on the stabilometer, i.e., water skiers and gymnasts, performed better during the test than both non-athletes and athletes of other sports. Interestingly, despite the different motor requirements of the two sports, soccer players and swimmers performed with similar proficiency on the balance task.

Hrysomallis made a study in 2011 where he found something interesting about gymnasts. Surprising considering that gymnasts do not maintain static postures for much more than 2 seconds during their routines. Gymnasts tended to have superior static unipedal balance, superior bipedal dynamic balance but not static bipedal balance. The ability to maintain balance is likely to be specific to the task and possibly not a general trait. Although gymnasts and rifle shooters appear to be the most commonly assessed for balance ability, it is the balance ability of soccer players that has been most widely compared with that of other athletes. Soccer players were found to have inferior dynamic bipedal or similar static and dynamic balance to gymnasts. They displayed similar dynamic bipedal or superior static unipedal balance to swimmers.

Previous, Laughlin & Mills (2000) talked more about swimmers and their balance, it has long been said that good swimmers swim high on the water. Naturally people interpret that to mean that “I should try to be high on the water,” but your body doesn’t work like that. Your body is designed to sink, so what you want to learn to do is to sink in a horizontal position. We see Jackie swimming with 95 percent of her body mass under water and only five percent of her body mass above the surface. Balance is not about buoyancy or body fat. Someone with less body fat will sink a little bit further, someone with more body fat would sink a little bit less, but the difference is insignificant. I’m not short on body fat, but if you look at an underwater view of me swimming, you’d see the same thing. If you learn to sink in a horizontal position, your body creates far less drag. So a balanced swimmer gets to use his/her arms to lengthen the body line then glide in a long, slippery position. Laughlin (2015) contended in a magazine that if you want to swim efficiently we must undo an inbred terrestrial balance sense and primal instincts about position and movement. As land-dwellers, we spend most of our lives experiencing gravity vertically— from the ground up the spine. In the water, we experience gravity horizontally. On land, we stand on our balance. In water we hang from it–complicated by the fact that we hang unevenly. As we swim, gravity pulls our dense lower body down while buoyancy pushes air-filled lungs up. Legs-lower and chest-higher is the natural position of a human body in water. One problem this creates is a huge increase in drag. A more insidious problem is that while sinking legs aren’t usually fatal, that sensation—at least in a novice–sends the brain into panic mode. We instinctively respond to ‘that sinking sensation’ with frantic churning, creating a lot of commotion but little locomotion. If ‘okay’ swimmers waste 97% of energy, survival swimmers might be 99% inefficient—explaining why even a highly conditioned marathon runner can feel exhausted after a single lap as a new swimmer.

Following a study conducted at Pennsylvania State University during the 1956-1957 academic year, Elmer A. Gross, Hugh L. concluded that: the measured dynamic balance is not a haphazard factor and can be an important factor in speed and ability swimming. Additional studies are needed to determine whether there is a cause and effect relationship between these factors. Gross and Thompson have made a research about relationship of dynamic balance to speed and to ability in swimming (2013) where they discover high and significant values between dynamic balance (as measured by the Base Teat) and speed in swimming (-.75 2 .05), and dynamic balance and ability in swimming (.65 2 .07). Also, *t* ratios calculated between these same abilities indicated that dynamic balance is not a chance factor and may be an important factor in speed and in ability in swimming. Further study is needed to determine whether there is a cause and effect relationship between these factors.

About swimmers also talked about Hsu *et.al.* (2010) that have checked the balance of the swimmers to assess the effects of swimming on engine control at the upper extremities and on the balance of the elderly. The eye hand coordination was evaluated by calculating the average reaction time required to accurately point the center of the target sensors that come in three different sizes (1 cm, 1.5 cm, and 2 cm in diameter). The SMART Balance Master device was used to measure posture balance. The maximum stability, the center of pressure (COP) velocity, and the percentage of ankle strategy were obtained under six different balance conditions.

Butler *et.al.* (2014) just like other researchers had as its objective to examine how gender affects performance on the YBT-UQ in swimmers. They measured YBT-UQ performance for the left and right limbs in the medial, infero-lateral, and supero-lateral directions. The maximum score for each direction was normalized to upper extremity length. Performance on several YBT-UQ indices was worse for female than male collegiate swimmers. These results may have implications for the use of preseason and return-to-sport testing in swimmers as a measurement of upper quarter function and symmetry. Norasteh *et. al.* (2012) has conducted a balance study with a different objective: the aim of was to compare static and dynamic balance among athletes competing or training in swimming, soccer, basketball and gymnastics. The Balance Error Scoring System (BESS) and the

Star Excursion Balance Test (SEBT) were used to evaluate the static and dynamic balance, respectively. The analysis of variance was performed twice, once for each static and dynamic balance, and the Tukey model was used for multiple comparisons to help control infusion of alpha. The results of this study showed that female swimmers showed lower static balance compared to gymnasts (P = 0.002) and soccer players (P = 0.04), and basketball players showed a lower dynamic balance compared to gymnasts (P = 0.008).

The **aim** of this research was to identify de level of the balance skills of the swimmers (as case studies) by testing the static and dynamic balance as a sensorial response to visual stimuli. In order to achieve this purpose we focused on using a device that will provide us to measure the proprioceptive response of the subjects involved in this research and to give a visual feedback in order to perform the established tests.

Materials and methods

Participants

The study regarded seven subjects (three males and four female) approached as case studies, performance swimmers, medalists at National Championships, between the ages of 11 - 23 years (16.4 ± 4.45 years), a body mass between 46 - 87kg (65.86 ± 16.32kg) and a height between 1.51 - 1.93m (1.70 ± 0.16m).

Procedures

The work took place at the Human Performance Research Center laboratory and we used as testing tool the Balance Miniboard platform manufactured by Sensamove. The subjects were tested for static and dynamic balance having visual feedback in real time by looking at the notebook's display. As a mode of execution, the subjects individually ascended to the balance platform in the right position, with slightly flexed legs, palms on shoulders and raised elbows (so that the trunk and the arms had an angle of about 90°). Each test lasts 30 seconds, while the subject has to stay as balanced as possible; to move the body mass from left to right, front and back.

Data analysis

The data were tabled and analyzed according to the protocol that was provided by the platforms' software and by viewing the figures and charts that were obtained by the subjects at the end of each balance test. We had exported the data from the tables of the protocol recorded by each subject and put them in a global table in order to be able to present the results for each balance test. The assessment of the data was done by appreciating the statistical indicators given by the software.

Results

After each test the balance miniboard software provided the results in degrees vs. time as well as in graphs presenting the way that each subject performed during the two neuromuscular tests (static and dynamic balance). The graphs revealed the "shape" of the balance capacity for each test from two perspectives: the way that the visual feedback of each test was given and the results of the test as average per second (fig.1 - 21). The software also provided a performance score expressed in percentage (%) (fig. 1 - 21) and the average deviation on the four ways (front, back, left and right) expressed in degrees (tables 1, 2 and 3).

Table. 1. The results of the static balance test (average per second) - S_1, S_2, S_3, S_4, S_5, S_6, S_7

Time (sec)	***S1***		***S2***		***S3***		***S4***		***S5***		***S6***		***S7***	
	Left - Right	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**
1	-0.39°	-0.62°	0.70°	0.60°	-0.78°	-0.69°	1.28°	3.52°	1.55°	0.12°	-0.46°	-2.70°	2.03°	0.76°
2	-2.10°	-0.63°	0.70°	0.27°	-0.43°	-0.79°	0.39°	1.81°	-0.11°	0.26°	-0.96°	-2.68°	-0.03°	-2.20°
3	-0.70°	-0.43°	0.64°	1.70°	-0.25°	-0.72°	2.13°	0.95°	0.84°	0.93°	-3.25°	-0.66°	-1.12°	-1.66°
4	-0.61°	-0.68°	1.22°	2.59°	0.31°	-0.28°	2.40°	0.63°	3.14°	0.21°	-0.51°	-1.11°	-1.66°	2.58°
5	-0.35°	-0.67°	-0.06°	2.14°	-1.37°	0.63°	0.51°	0.91°	1.62°	-0.29°	-0.90°	1.50°	0.59°	0.61°
6	-0.54°	-1.77°	-0.58°	5.04°	1.31°	1.15°	2.00°	2.67°	2.30°	-0.20°	-2.63°	3.03°	-0.54°	0.66°
7	-0.78°	-0.32°	0.79°	0.35°	-0.71°	-0.30°	-0.99°	2.88°	1.12°	-0.98°	-0.81°	2.74°	-0.59°	-0.74°
8	-0.31°	-1.06°	2.13°	1.40°	1.70°	-0.35°	3.75°	6.36°	-0.37°	1.18°	0.28°	0.74°	-0.19°	0.29°
9	-0.94°	-0.44°	1.70°	1.59°	-1.44°	0.10°	3.08°	1.59°	-1.02°	1.83°	0.88°	-1.95°	0.89°	0.96°
10	0.59°	-0.28°	1.85°	1.53°	0.77°	-0.51°	0.84°	1.04°	-0.38°	1.47°	-1.16°	-1.26°	0.56°	-0.12°
11	0.42°	-1.41°	2.97°	0.16°	-0.81°	0.89°	1.28°	0.71°	-0.31°	0.18°	-0.18°	-0.89°	0.79°	-0.68°
12	-0.45°	0.75°	1.63°	1.80°	-0.33°	1.77°	-0.79°	-0.34°	-0.84°	-0.59°	1.85°	-0.75°	0.46°	-1.80°
13	-0.78°	0.60°	1.38°	0.64°	-1.11°	1.32°	0.27°	-1.46°	1.04°	2.51°	0.68°	1.67°	0.63°	-0.70°
14	-1.42°	-0.32°	0.04°	-0.48°	-1.11°	0.24°	1.95°	0.13°	2.86°	1.46°	-5.70°	2.55°	0.79°	1.58°
15	-1.11°	0.14°	1.12°	-0.12°	-0.59°	0.63°	2.99°	1.46°	1.85°	-0.29°	0.64°	0.26°	-0.36°	-0.62°
16	0.34°	-1.12°	0.64°	1.27°	0.26°	1.39°	4.91°	-0.51°	0.85°	5.27°	-1.82°	2.03°	0.43°	-0.01°
17	-0.35°	-0.11°	-0.37°	1.11°	0.22°	0.31°	2.16°	-1.69°	2.96°	0.89°	-0.67°	-4.04°	0.80°	0.32°
18	-1.26°	-0.64°	-0.06°	-0.31°	-0.57°	-1.25°	-0.61°	1.29°	1.21°	1.09°	-0.57°	-2.43°	0.65°	0.87°
19	-0.39°	-0.13°	0.52°	0.60°	1.69°	0.16°	-3.02°	4.89°	1.94°	-0.05°	-0.49°	-1.22°	1.02°	0.14°
20	-0.93°	-0.74°	0.63°	-0.30°	-0.23°	-0.37°	1.07°	0.50°	2.73°	-0.11°	0.55°	-0.75°	0.72°	-0.34°
21	0.78°	-0.82°	0.46°	0.54°	2.04°	-2.04°	-4.17°	-7.95°	1.02°	-2.34°	0.28°	-0.22°	-0.44°	-0.73°
22	-1.25°	0.57°	-1.00°	0.61°	-2.39°	-1.12°	2.54°	-2.52°	4.87°	2.73°	-1.93°	0.96°	-0.39°	0.13°
23	-0.89°	0.45°	0.63°	-1.15°	-0.66°	6.08°	-1.63°	-3.10°	1.47°	4.18°	-0.95°	-0.46°	0.07°	-0.40°
24	-1.50°	0.65°	2.26°	0.32°	2.34°	0.52°	-0.01°	2.17°	2.15°	1.25°	-0.24°	0.09°	-0.57°	0.04°
25	-0.31°	-0.08°	2.01°	-0.41°	1.55°	-1.12°	6.20°	4.29°	0.55°	-0.21°	-0.23°	-0.29°	-0.35°	-0.57°
26	-2.80°	-0.29°	0.73°	0.40°	-1.00°	1.09°	5.48°	-2.61°	1.31°	3.62°	0.09°	-0.13°	0.21°	0.20°
27	-0.10°	-1.08°	0.51°	0.03°	-1.93°	0.73°	1.48°	-2.36°	6.91°	-1.67°	0.69°	0.11°	0.08°	0.83°
28	2.17°	-0.09°	0.37°	0.97°	0.20°	-0.26°	-3.90°	-0.74°	6.94°	-1.01°	-1.47°	1.11°	0.33°	1.31°
29	-1.21°	1.00°	-1.36°	0.87°	0.22°	-0.49	2.38°	0.58°	4.74°	3.44°	-2.11°	0.09°	0.14°	0.68°
30	-1.55°	0.78°	0.67°	-0.62°	0.52°	0.49	-0.17°	-0.53°	8.79°	0.74°	-2.20°	-1.22°	0.71°	-0.84°

Table 1 shows the results of the ***static balance*** test obtained by the subjects surveyed. Data analysis can be done by comparing to **level 0** (reference) that represents the level at which subjects manage to maintain their balance without oscillations (balancing) towards either of the two planes (frontal and sagital).

In the case of *static balance results in the sagital plane* (left-right), the negative values represent the deviation from level 0 to the left, while positive values suggest deviations to the right. In what concerns the results obtained in the *frontal plane*, positive values represent the deviations from level 0 to the front and the negative ones point backward deviations.

Considering these aspects, we can say that:

a) with respect to ***frontal oscillations***:

- the data of subjects S_1 and S_6 show a higher frequency of the negative values than the reference level compared to the positive ones (22/8 respectively 17/13);

- Subjects S_2, S_3, S_4, S_5 and S_7 show fewer negative values compared to positive ones (7/23; 14/16; 11/19; 11/19; 14/16);

b) regarding to ***sagital oscillations***:

- the dynamics of the negative values are similar to those recorded in the frontal oscillations, in addition to the subjects S_1 (25/2) and S_6 (21/9), the more frequent negative values being presented also by subject S_3 (17/13);

- the other four subjects (S_2, S_4, S_5 and S_7) had fewer negative values compared to the positive ones (6/24, 9/21, 6/24 and 11/19) respectively;

Fig. 1 Static balance test - S_1

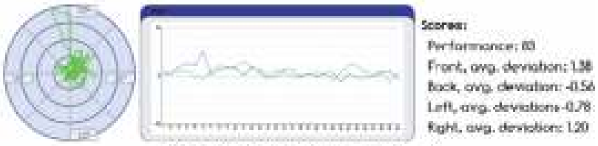

Fig. 2 Static balance test - S_2

Fig. 3.Static balance test - S_3

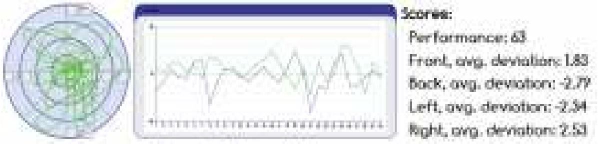

Fig. 4. Static balance test - S_4

Fig. 5. Static balance test - S_5

Fig.6. Static balance test - S_6

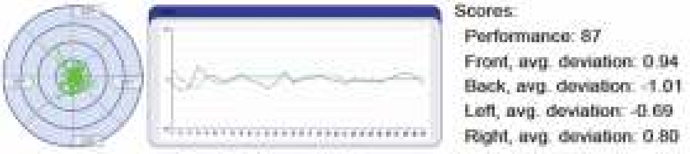

Fig. 7. Static balance test - S_7

The values of the scores illustrated in fig. 1-7 expresses (in percents) how the subject manages to maintain its balance in the center or within the preset area, as well as the mean (in degrees) of the oscillations in the two planes (frontal and sagital). By analyzing the performance values we can see that the minimum value was recorded by subject S_4 and 63% (Fig.4) and the highest values were obtained by subjects S_7 and S_1, respectively 87% and 86 (Figure 7). Subjects S_2, S_3, S_5 and S_6 presenting intermediate values of the limits of the research group, respectively 83%; 81%; 66% and 77% (figures 2, 3, 5 and 6).

Analyzing the deviations in the two planes, it can be observed that, at **static balance** level, the subjects had achieved an average values compared to **level 0** as follows:

- between -0.69^0 and -2.34^0 for the sagital plane (oscillations to the left);
- between 0.80^0 and 2.74^0 for the sagital plane (oscillations to the right);
- between -0.56^0 and -2.79^0 for the front plane (backward oscillations);
- between 0.58^0 and 2.18^0 for the front plane (forward oscillations).

Table. 2. The results of the front – back dynamic balance test (average per second) - S_1, S_2, S_3, S_4, S_5, S_6, S_7

Table 2 shows the results of the ***dynamic balance*** test which assumes the orientation of the neuromotor response *front and back* according to the predefined model and the data show a smaller difference between the number of positive and negative values compared to those recorded in the case of static blance. By comparing the positive and the negative values we can state the following:

Time (sec)	***S1***		***S2***		***S3***		***S4***		***S5***		***S6***		***S7***	
	Left - Right	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**
1	-1.12°	-3.63°	0.20°	-4.84°	1.05°	-3.66°	-0.46°	-4.31°	1.95°	-5.26°	0.09°	-5.24°	-0.58°	0.94°
2	-0.99°	-1.18°	-0.91°	3.26°	1.55°	2.15°	-0.13°	1.81°	3.08°	-0.89°	-0.99°	-0.77°	-0.85°	-3.16°
3	-1.15°	0.53°	2.25°	-1.07°	-2.17°	6.50°	2.40°	-4.81°	0.26°	4.91°	-0.29°	4.71°	0.44°	-5.33°
4	-0.53°	2.09°	0.24°	-0.94°	-3.14°	-5.57°	4.25°	1.29°	0.78°	2.96°	2.63°	3.65°	1.14°	-1.22°
5	-1.92°	6.02°	-0.40°	-5.99°	-2.89°	-1.75°	1.55°	7.22°	-1.71°	-5.68°	1.94°	-1.97°	0.12°	6.86°
6	-0.42°	4.02°	1.20°	-2.15°	-0.43°	3.98°	-2.16°	-4.92°	1.09°	-5.22°	0.20°	-5.93°	-1.09°	4.81°
7	0.53°	-0.83°	-1.06°	1.10°	-2.38°	8.83°	0.67°	-3.83°	0.69°	7.12°	-1.91°	0.11°	0.59°	1.69°
8	-0.49°	-0.16°	0.36°	6.77°	-2.17°	-4.03°	2.03°	5.59°	1.27°	5.11°	-3.86°	6.34°	0.72°	-2.00°
9	-0.94°	-4.80°	0.05°	2.18°	-0.14°	-4.78°	1.10°	-5.87°	-0.48°	-7.74°	-0.80°	-4.05°	-0.46°	-2.89°
10	0.00°	-4.59°	2.04°	-5.18°	1.82°	4.22°	3.40°	-0.20°	-0.09°	2.13°	0.77°	-2.91°	0.49°	1.74°
11	-0.82°	-1.59°	-0.73°	0.21°	1.15°	-3.89°	-2.18°	7.38°	0.65°	7.17°	1.18°	1.16°	0.16°	4.70°
12	-0.72°	0.43°	-0.42°	3.99°	-4.00°	-6.36°	-0.59°	-5.50°	-0.73°	-6.27°	1.49°	2.48°	-0.11°	0.38°
13	-1.40°	2.64°	-0.33°	2.60°	-0.41°	-5.72°	1.48°	-1.63°	-1.36°	-6.15°	0.74°	-2.51°	0.09°	-3.82°
14	1.71°	6.85°	0.71°	-0.58°	2.43°	2.13°	0.66°	5.57°	-0.96°	7.42°	0.52°	-5.69°	0.83°	-6.28°
15	-1.01°	5.72°	-0.82°	-1.79°	-1.39°	10.86°	-0.91°	-6.94°	1.58°	2.38°	-2.29°	2.39°	0.21°	-2.61°
16	0.41°	-1.17°	-0.38°	8.55°	-5.10°	0.21°	-2.37°	2.22°	0.93°	-9.45°	-1.37°	0.07°	0.47°	4.50°
17	-0.67°	-2.10°	-0.50°	-3.47°	-3.33°	-5.85°	-1.80°	5.23°	2.06°	-2.61°	1.03°	-4.45°	1.31°	4.88°
18	-2.80°	-6.61°	-0.74°	-2.09°	0.22°	-5.84°	1.37°	-6.07°	1.73°	7.48°	0.04°	-1.50°	-0.30°	0.65°
19	-1.46°	-2.92°	-0.11°	2.07°	2.77°	0.13°	3.55°	4.89°	-1.78°	-1.53°	1.11°	3.95°	-0.93°	-3.52°
20	-2.27°	-4.40°	0.70°	2.14°	1.64°	7.39°	0.03°	-0.61°	-1.76°	-9.51°	-1.69°	-0.89°	0.57°	-6.14°
21	-0.17°	-6.31°	0.64°	5.74°	-1.44°	8.80°	-1.58°	-8.61°	-1.26°	-5.45°	-0.68°	-6.68°	-0.93°	-0.71°
22	-2.14°	-3.41°	-0.37°	-2.49°	0.38°	-4.49°	1.69°	2.83°	-1.71°	2.34°	-0.20°	-3.04°	-0.99°	4.72°
23	-1.11°	-1.70°	-0.09°	-1.68°	-0.87°	-3.08°	-2.50°	6.65°	0.19°	7.84°	-1.32°	9.05°	0.85°	1.19°
24	-0.75°	1.45°	-0.21°	1.75°	4.92°	2.04°	-1.08°	-8.10°	-1.90°	2.13°	1.87°	3.73°	-0.59°	-3.06°
25	0.17°	2.62°	-1.65°	4.64°	2.34°	7.71°	-1.52°	-3.79°	1.31°	-8.95°	0.64°	-7.17°	-0.20°	-4.49°
26	-0.21°	6.54°	1.43°	-5.95°	-1.08°	2.04°	0.94°	2.08°	2.07°	-1.13°	-0.86°	-5.80°	-0.80°	-4.81°
27	-0.14°	1.87°	-0.59°	3.78°	-0.19°	-6.72°	2.53°	-7.48°	2.11°	7.05°	-1.80°	-0.04°	0.15°	0.32°
28	-0.03°	0.89°	0.19°	0.78°	-1.45°	-0.64°	0.84°	6.76°	1.81°	4.86°	1.69°	1.38°	-0.24°	3.10°
29	-0.88°	-0.72°	1.05°	-5.29°	-1.19°	8.02°	-5.84°	5.42°	0.16°	-3.76°	0.53°	1.70°	0.55°	3.85°
30	-0.49°	-3.69°	0.31°	4.53°	-1.36°	7.19°	-3.33°	-8.70°	-0.73°	-6.49°	0.46°	2.79°	-0.07°	1.93°

- *in the sagital plane*, the subjects S_1, S_2 and S_3 exhibit negative values in a larger number compared to the positive ones (25/5, 16/14, respectively 19/11), whereas the subjects S_4 and S_7, respectively S_5 and S_6 record identical negative frequencies but less than the others (14/16, 14/16, 12/18, 12/18);
- *in the frontal plane*, the differences recorded are much lower compared to those recorded in the static balance test, 6 of the subjects having two (S_2, S_3, S_4, S_5, S_6, S_7) and one (S_1) presenting three values differences between the negative and the positive ones (14/16; 14/16; 16/14; 16/14; 16/14; 14/16; respectively17/13).


Scores:
Performance: 94
Left, inside: 71
Right, inside: 23
Front, avg. deviation: 3.22
Back, avg. deviation: -3.01
Left, avg. deviation: -1.15
Right, avg. deviation: 0.70

Fig8. Dynamic front-back balance test - S_1


Scores:
Performance: 96
Left, inside: 53
Right, inside: 43
Front, avg. deviation: 3.69
Back, avg. deviation: -3.62
Left, avg. deviation: -0.77
Right, avg. deviation: 1.07

Fig9. Dynamic front-back balance test -S_2


Scores:
Performance: 47
Left, inside: 22
Right, inside: 25
Front, avg. deviation: 5.58
Back, avg. deviation: -4.72
Left, avg. deviation: -2.52
Right, avg. deviation: 1.66

Fig10. Dynamic front-back balance test -S_3


Scores:
Performance: 54
Left, inside: 26
Right, inside: 26
Front, avg. deviation: 5.43
Back, avg. deviation: -5.94
Left, avg. deviation: -2.03
Right, avg. deviation: 2.07

Fig11. Dynamic front-back balance test -S_4

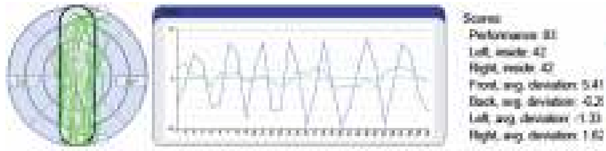
Scores:
Performance: 83
Left, inside: 42
Right, inside: 42
Front, avg. deviation: 5.41
Back, avg. deviation: -6.2
Left, avg. deviation: -1.33
Right, avg. deviation: 1.62

Fig12. Dynamic front-back balance test - S_5


Scores:
Performance: 70
Left, inside: 35
Right, inside: 35
Front, avg. deviation: 3.54
Back, avg. deviation: -4.37
Left, avg. deviation: -1.48
Right, avg. deviation: 1.42

Fig13. Dynamic front-back balance test -S_6


Scores:
Performance: 96
Left, inside: 42
Right, inside: 54
Front, avg. deviation: 3.34
Back, avg. deviation: -3.57
Left, avg. deviation: -0.77
Right, avg. deviation: 0.63

Fig14. Dynamic front-back balance test -S_7

In the above figures (fig. 8-14) we can see the results highlighted as percentages (the total performance consisting of the performance to keep the balance front - back within the preset mark) and in the form of average deviations recorded in the sagital and frontal plane, expressed in degrees. Total performance data are between 47% (subject S_3) and 96% (S_2 and S_7 subjects), the other four subjects achieving 54%, 70%, 83%, and 94% chronological results. Although subjects S_2 and S_7 have identical performance values, it is interesting that out of a total of 96%, the two show differences in bipodal neuromuscular control. Thus, subject S_2 manages to respond to the stimulus with a balance capacity of 53% to the left and 43% to the right one; in antithesis, the subject S_7 exhibits n balance capacity oriented more towards the right (42% to the left and 54% to the right).

Table. 3. The results of the left – right dynamic balance test (average per second) - S_1, S_2, S_3, S_4, S_5, S_6, S_7

Time (sec)	***S1***		***S2***		***S3***		***S4***		***S5***		***S6***		***S7***	
	Left - Right	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**	**Left - Right**	**Front - Back**
1	-0.98°	-3.43°	-2.49°	-2.78°	-5.92°	-2.13°	-0.30°	-1.11°	-4.68°	0.11°	3.19°	-0.85°	0.14°	0.31°
2	-1.42°	-1.97°	5.21°	-2.32°	-6.29°	-1.69°	5.35°	-2.10°	-1.06°	-1.25°	5.07°	-0.40°	1.61°	0.66°
3	-2.33°	-2.00°	5.56°	-0.52°	6.50°	-0.72°	3.92°	-3.34°	0.95°	0.66°	-7.92°	-1.95°	2.00°	2.31°
4	-3.10°	-1.81°	-6.50°	-2.28°	4.67°	-1.53°	-7.30°	-3.55°	5.82°	-3.62°	-4.67°	-3.00°	1.36°	-0.31°
5	-1.68°	-1.36°	1.57°	-0.56°	-9.23°	-1.14°	-8.51°	-0.03°	7.81°	0.15°	1.20°	-4.12°	-0.66°	-0.11°
6	1.73°	-2.65°	6.63°	0.53°	-6.22°	-3.91°	1.68°	-0.21°	6.42°	-0.14°	1.52°	1.24°	-5.79°	-0.30°
7	2.71°	0.16°	-7.22°	2.43°	3.96°	-2.44°	7.38°	-0.03°	-1.31°	0.16°	7.68°	3.44°	-8.09°	1.17°
8	5.19°	-0.02°	-0.26°	-0.75°	6.09°	-1.21°	5.25°	2.82°	-4.72°	0.15°	6.22°	1.37°	-1.04°	-0.43°
9	0.60°	-0.28°	5.36°	1.00°	5.42°	0.77°	2.04°	-3.97°	-3.20°	-0.31°	4.95°	-2.04°	1.49°	-0.57°
10	-1.83°	-0.63°	-7.30°	0.04°	-9.74°	1.93°	-6.66°	-2.76°	-7.38°	-1.83°	-3.99°	0.83°	3.88°	-0.76°
11	-6.90°	0.94°	-3.84°	-0.71°	-1.43°	-1.90°	-7.83°	1.35°	-0.29°	-2.87°	-10.05°	1.75°	-0.54°	0.76°
12	-4.80°	0.54°	-2.62°	-1.86°	8.63°	1.63°	7.31°	2.59°	7.92°	-2.87°	-1.35°	-3.07°	-3.86°	-0.20°
13	0.78°	-0.76°	4.46°	0.72°	-5.03°	-1.28°	5.63°	0.53°	8.46°	3.81°	7.52°	0.68°	-6.35°	0.05°
14	3.02°	0.87°	-7.30°	-0.50°	-4.56°	-0.52°	-9.53°	-2.02°	0.67°	1.78°	5.14°	-0.27°	-0.27°	-1.11°
15	5.67°	-0.72°	-3.73°	0.38°	7.88°	0.29°	-6.56°	-0.07°	-0.82°	-2.10°	-2.71°	0.26°	3.28°	-0.07°
16	7.28°	1.30°	2.46°	0.36°	4.41°	-0.40°	7.52°	-0.53°	-2.10°	-2.79°	-6.68°	1.64°	-0.73°	-0.30°
17	0.92°	-1.98°	-4.29°	-1.71°	-10.14°	-0.05°	6.89°	2.23°	-5.64°	-1.43°	0.94°	-1.94°	-6.29°	-0.64°
18	-1.02°	-1.19°	1.28°	-2.76°	-3.74°	-0.95°	-5.46°	1.25°	-3.23°	-1.37°	1.32°	-0.64°	-4.91°	0.08°
19	-0.29°	-1.34°	3.11°	-0.80°	8.62°	0.25°	-8.04°	2.92°	7.26°	1.03°	7.13°	0.70°	0.36°	-0.41°
20	-3.07°	-2.23°	-8.19°	-1.04°	0.87°	-0.19°	6.56°	0.11°	7.78°	-1.91°	5.49°	-1.64°	2.57°	1.14°
21	-7.79°	-1.37°	4.73°	1.16°	-9.76°	0.76°	4.09°	-0.36°	2.15°	2.42°	1.34°	0.55°	3.29°	-1.22°
22	-2.56°	-0.31°	4.88°	1.45°	-7.01°	3.12°	-6.22°	-0.90°	-4.30°	6.14°	-6.94°	2.81°	4.11°	-0.45°
23	-0.66°	-1.25°	-4.48°	0.74°	3.24°	-1.34°	-2.19°	2.32°	-6.05°	-0.28°	-7.60°	-0.16°	5.43°	0.02°
24	1.76°	-0.75°	-0.81°	0.28°	7.13°	0.17°	8.63°	0.44°	-7.52°	4.58°	-1.24°	0.28°	1.56°	-1.85°
25	5.57°	0.20°	5.50°	0.16°	-2.09°	2.89°	-0.44°	-4.86°	-0.19°	-1.78°	8.66°	1.85°	-2.46°	-1.73°
26	6.07°	-0.72°	-2.82°	-0.52°	-6.29°	1.35°	-8.96°	1.28°	3.10°	-1.82°	7.24°	-1.13°	-5.03°	1.68°
27	1.54°	-0.21°	1.56°	0.00°	1.70°	-2.36°	4.68°	4.92°	7.35°	0.68°	4.22°	-3.07°	-6.83°	-1.36°
28	-1.54°	-0.20°	7.45°	0.76°	8.75°	0.82°	7.16°	-3.44°	6.21°	-1.78°	1.69°	-0.27°	-4.27°	0.39°
29	-3.04°	0.56°	-0.49°	0.40°	4.25°	0.84°	-1.41°	-3.31°	2.37°	-3.04°	-6.88°	3.41°	-0.24°	-0.66°
30	-4.49°	0.29°	-3.84°	-1.64°	-0.59°	-0.09°	-8.72°	-3.01°	-1.31°	-0.79°	-2.83°	0.84°	6.22°	0.09°

In Table 3 there are presented the results obtained in the ***dynamic balance test*** in which the stimulus assumed the reorganization of the lateral neuromotor response (left-right). Compared to the results of the other two previously measured balance patterns, this test reveals smaller differences in terms of negative and positive values, except for S_1 (17/13). Thus, *in the frontal plane*, subjects S_2 and S_6 present equal numerical values in both negative and positive sense (15/15) while subjects S_3, S_4, S_5 and S_7 point to identical differences (18/12) in favor negative values. In *the sagital plane*, subject S_1 again makes a discordant note, this time getting bigger differences between the two categories of values (22/8 towards the negative ones). Subjects S_2, S_5 and S_7 show a difference of only two negative values (16/14), and subjects S_3 and S_4 record identical values in both senses (15/15).

Fig. 15. Dynamic left - right balance test - S_1

Fig.16. Dynamic left - right balance test - S_2

Fig. 17. Dynamic left - right balance test - S_3

Fig. 18. Dynamic left - right balance test - S_4

Fig. 19. Dynamic left - right balance test - S_5

Fig. 20. Dynamic left - right balance test - S_6

Fig. 21. Dynamic left - right balance test - S_7

Figures 15-21 illustrate minor differences between mean deviations of frontal and sagital planes, with minimum values ranging from 0.98^0 to -1.30^0, respectively -2,90^0-3,38^0 and maximum values ranging from 2,39^0 to -2,57^0 respectively -6,82^0 and 5,84^0 respectively. Performance percentages are between 40% for S_4 and 91% for S_1, but interestingly these values are not evenly distributed across the front to both subjects. Although it obtains a low value, the subject S_4 manages a distribution of balance approximately equal to both forward (19%) and back (20%), similar to the case of the S^6 subject which achieves 53% distributed 27% front and 26% back. In the other 5 cases the performance values indicate a dynamic backward balance: S_1 (24% forward - 68% back), S_2 (41% forward - 46% back), S_3 (26% S_5 (25% forward - 39% back), S^7 (36% forward - 53% back).

Discussions and conclusions

This research aimed to identify the level of balance ability, specific to swimmers, in the form of case studies, by measuring the static and dynamic balance as sensory response to visual stimuli. The interpretation of the results was based on the data provided by the platform software, these being expressed in four ways (front, back, left, right) corresponding to the frontal and sagital planes.

Regarding the static balance ability, the subjects presented low values of the average deviations from the reference point (0) for all four measuring points, among them, only the S_4 subject recording the highest values (1,830 forward and -2,79^0 towards backwards, -2,34^0 to the left and 2,53^0 to the right).

The performances obtained in the front-to-back dynamic balance measurement showed the highest values, three of the subjects achieving percentages over 90% (S_1 - 94%, S_2 - 96% and S_7 - 96%). On the opposite side, the lowest performance values were recorded by S_3 (47%) and S_4 (54%). One interesting thing is that two of the three subjects with the highest performance values showed greater deviations to the left during the neuromuscular task, which can emphasize a better dynamic balance on the left side of the bipedal support . This situation is also found in the measurement of the dynamic balance in the sagital plane, where the same subjects got the best performances, this time ranging between 87% (S_2) and 91% (S_1), with an intermediate performance of 89%, registered by S_7. Similar to the measurements of the dynamic balance in the frontal plane, and the case of the dynamic balance in the sagital plane, we find the same tendency to orient the sensory response towards a certain sense (backwards), the subjects failing to adjust their balance equally. This aspect demonstrates a better ability to reorganize the neuromuscular response under posterior bipedal support (towards the heel).

The research has highlighted that balance is a basic element of swim training that can provide details of neuromuscular control identified by assessing the dynamics of postural oscillations in the frontal and sagital plane, the information that can be obtained representing objective indices regarding the ability to sensory structural reorganization under different conditions of motor tasks.

The results obtained by the subjects included in the research as case studies highlighted the following particular aspects of the experimental sample:

- S_1, S_2 and S_7 had the best performances, this being explained by the anthropometric and sports training features (S_1 and S_2 are seniors and S_7 is part of the children category);
- at the opposite pole, the most heterogeneous results were obtained by S_3 and S_4, swimmers with deficiencies of the spine.

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