# The importance of visual information on the maintenance of balance in wakeboarders.

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## Abstract

The importance of visual information for maintaining static balance in wakeboarders was investigated in this study. Forty-two subjects, matched for age, height, weight and sex formed a wakeboard and a control group. All subjects were measured at ten, twenty and thirty seconds for the displacement of the centre of pressure (postural sway) during static balance tasks. Three increasingly difficult balance tasks were used with and without removal of vision. The results showed that in general wakeboarders performed better on the balance tasks in the anterior-posterior direction than non-sportsmen. Visual information became more important when the task was made more difficult. No relation was found between the level of performance of the wakeboarder and the importance of visual information for maintaining static balance. Visual information is very important for balance control for both wakeboarders and non-sportsmen. It was concluded that the importance of visual information for maintaining balance is increased as the tasks become more difficult. Finally the findings also demonstrated that wakeboarders develop specific modalities of balance, which are only partly transferable to static posture control tasks.

## Introduction

Wakeboarding is a novel sport where an athlete rides a specially designed board skimming over the surface of the water. If a motorboat tows the wakeboarder then the wake of the boat modulates the surface. Alternatively the board can be propelled using a cable and winch. The objective is to perform various acrobatic tricks. Performing the complex movements, similar to those performed by gymnasts and dancers (Vuillerme et al., 2001a), wakeboarders require a great sense of balance, Kiting is similar to wakeboarding only in this case the board is being propelled by a kite.

Postural stability is defined as *the ability to maintain or control the centre of mass in relation to the base of support to prevent falls and complete desired movements.* Balancing is the process by which postural stability is maintained (Westcott et al., 1997). The control of posture is known to be critical for both the acquisition and control of motor abilities and is an essential requirement for physical activities in daily life (Vuillerme et al., 2000). In wakeboarding and other motor activities the dynamic stability of the posture during movement is dependent on the subject's capacity to maintain balance in a constant altering environment (Hugel et al., 1999). Balancing depends on feedback of sensory information from visual, vestibular and somatosensory sources. The central nervous system processes the information by comparing them to a 'postural' body scheme built by the subject's anterior experiences, and on reflex motor activities (Hugel et al., 1999).

It has been proved in one study (Kioumourtzoglou et al., 1997) that athletes can demonstrate a better sense of balance than sedentary subjects. This issue is under debate in the context of the two leading theories proposed for the transfer of motor abilities. General motor ability hypothesis suggests that any human skill should remain observable among various tests. However, the transfer of motor ability might not be such a simplistic mechanism. In fact, Henry's hypothesis predicted that transfer among skills should be quite low because motor ability is specific to a particular task (Vuillerme et al., 2001a).

The current study attempts to determine the importance of visual information on the maintenance of balance in wakeboarders by:

1. Investigating the hypothesis that wakeboarders demonstrate a better sense of balance than sedentary subjects under different static conditions.
2. Investigating the hypothesis that wakeboarders and non-sportmen dependend more on visual information to maintain static balance when task difficulty is increased.
3. Investigating the hypothesis that a negative relation exists between the level of performance of the wakeboarder and the amount of variation of postural sway in different conditions.

## Methods

### Participants

Two groups of subjects were formed, one group existed of wakeboarders and the other existed of people who do not participate in regular physical activities or who participate in sport activities that do not require high balance skills. The groups were constructed so that there was no significant difference in age, weight and height, because body-properties are known to be determinant, for postural tasks (Berger et al., 1992) (see table 1.).

The wakeboarding group consisted of 15 males ranging from 16 to 48 years (mean: 23.6 years) and 6 females ranging from 14 to 31 (mean: 20.5 years). It was limited to participants with experience of wakeboarding and/or kiting.

The average time spent wakeboarding was 13.75 hours a week (range: 4-48 hours per week) and the time spent kiting by the three participants was 2, 5 and 8 hours a week.

Eight of the wakeboarders had ongoing injuries (see table 2.). However all of them were able to wakeboard unencumbered. A six month injury free criteria was used for injuries involving an ankle, following the results of Holme et al. (1999), who reported that four months after injury, reduced ankle strength and postural control were no longer noticeable. Thirteen of the twenty-one wakeboarders participated in competitions at national level or higher and six wakeboarders were involved in a sporting activity other then wakeboarding.

The control group consisted of twenty-one healthy subjects of which fifteen did not participate in any regular physical activity and had no long-term experience in any other sporting activity requiring balance. Six subjects performed regular sport activities but not at a particularly high level and without need of great balance skills. Fifteen males ranging from 15 to 51 years, (mean: 24.3 years) and six females between 13 and 25 years (mean: 19.5 years) formed the control group. One woman reported a history of low back pain (table 2.).

Table 1. Body properties in expert and control group.

| | Expert group (males) | Expert group (females) | Control group (males) | Control group (females) |
|---|---|---|---|---|
| **Height (m)** | 1.79 (1.75-1.86) | 1.71 (1.63-1.82) | 1.82 (1.71-1.90) | 1.67 (1.58-1.73) |
| **Weight (kg)** | 75 (65-98) | 61.5 (45-73) | 75 (55-101) | 55 (49-63) |
| **Values given are group mean and (range)** | | | | |

Table 2. Current Injuries..

| | Ankle | Knee | Hip | Back | Eardrum |
|---|---|---|---|---|---|
| **Number of subjects from expert group** | 2 | 3 | 1 | 0 | 2 |
| **Number of subjects from control group** | 0 | 0 | 0 | 1 | 0 |

**Apparatus**
A strain-gauge force platform made of four vertical pressure gauges and a statokinesimeter were used to measure postural behaviour in terms of cumulative magnitude of the variation of postural sway in the anterior-posterior (a-p) direction and in the lateral direction.

**Experimental Setup**
The force platform was levelled and positioned 1.5 meter from a wall in an environment free from as many perturbations as possible. The display of the statokinesimeter was placed on a spacer behind the participants such that it was not possible for them to monitor their own progress during the experiment. A Soehnle© digital scale was used (maximum weight 130 kg) to measure the participants weight.

**Design and Test Procedure**
After signing an informed consent, the participants were asked to complete a group specific questionnaire. The subjects were briefed about the purpose of the study and given an opportunity to ask questions before commencing the experiment. The participants were asked to perform three different static postural tasks whereby the visual source of information was manipulated per condition (see table 3). Tasks were made increasingly difficult by using a unipedal stand and a bag filled with air (Tilia© balance bag) which amplifies any loss of balance. The subjects were barefoot and the placement of their feet was predetermined. Before testing each condition the participants were given a verbal explanation of the procedure and asked to confirm their understanding. All experiments involved standing as still as possible in an upright position on the force platform for a 30-second period. The participants were told to place their hands behind their back, keep their head upright, fixate on a position in front of them and stand as still as possible. To initiate the different conditions the researcher used a count of five. On the count of one the participant took up position on the force platform. At the count of four the participant closed his eyes (for condition 2, 4 and 6) and lifted one foot (for condition 3 and 4). The measurement started on the count of five.

Placement of the feet on the bipedal task (the base task) was determined by fixed positioned blocks. For the unipedal task the participant had to place his foot of preference on a dotted line, which indicated the middle of the force platform. A Tilia© balance bag with a radius of 33 centimeters was used for the last task (condition 5 and 6). The amount of contact of the feet with the surface of the force platform had to be kept at a minimum while standing on the Tilia© balance bag. The position of the feet were the same as used in task 1. After performing each condition the participants took a short rest (<1 min).

Table 3. The conditions under which the static postural tasks were performed.

| Condition | Task | Eyes |
|---|---|---|
| *1* | Bipedal (base) | Open |
| *2* | Bipedal (base) | Closed |
| *3* | Unipedal | Open |
| *4* | Unipedal | Closed |
| *5* | Bipedal balance bag | Open |
| *6* | Bipedal balance bag | Closed |

**Statistical Analysis**

Statistical analyses techniques were applied to the data to evaluate the three postulated hypotheses.

Before analysing the data, a student t-test was performed to check whether the height, weight and age differed between the two groups. As mentioned earlier no significant ($p<0.05$) difference was found between the two groups.

Subjects who failed to stay on the platform for the required thirty seconds were given penalty scores. The following percentage was added to the worst cumulative variation of postural sway of all subjects to acquire a suitable penalty score:

- Falling once: five percent was added.
- Falling twice: ten percent.
- Falling three times: fifteen percent.

The first hypothesis was tested using a two-way analysis of variance (ANOVA). The amount of variation of postural sway was set as a dependent variable and the group and task as independent variables. Main effect of the independent variables was carried out for each ten-second period and direction (posterior-anterior and lateral sway). Analyses of variance (two groups x six conditions) was applied on the data for each time period and direction to find any significant interaction between group and condition. This allowed the current study to see if wakeboarders had a better maintenance of balance than non-sportsmen.

In order to test the second hypothesis a post hoc Scheffé-test was used to highlight significant difference. The sway for one task was compared under two different conditions (visual vs. non-visual) for each group separately. This was done to determine if the subjects performed differently with or without visual information.

The third hypothesis was tested using a Spearman's correlation between the level of wakeboarding and the cumulative magnitude of the variation of postural sway in the anterior-posterior and lateral direction. The objective was to see if a wakeboarder classified in the high level group showed lesser amount of variation of postural sway under different conditions during increasing task difficulty. A certified competition adjudicator determined the level of performance the wakeboarder using a scale from one to ten with ten being the highest level (mean: 5.0; range: 1.5-9).

## Results

ANOVA showed a significant main effect between the two groups (table 4) and between the different conditions (table 5). The wakeboard group showed a significant lower value of variation of sway then the non-sportsmen. A significant interaction between group and condition on the cumulative magnitudes of variation of postural sway was found in anterior-posterior direction in all time periods. For the lateral sway a significant difference between the two groups was only found after twenty seconds (table 6).

Table 4

**Main effect between groups**

| Time and direction | F-value | Sig. |
|---|---|---|
| *10 sec. anterior-posterior sway* | 26.509 | 0.000* |
| *20 sec. anterior-posterior sway* | 20.211 | 0.000* |
| *30 sec. anterior-posterior sway* | 17.869 | 0.000* |
| *10 sec. Lateral sway* | 13.540 | 0.000* |
| *20 sec. Lateral sway* | 10.853 | 0.000* |
| *30 sec. Lateral sway* | 9.307 | 0.000* |

*. The mean difference is significant at the .05 level.

Table 5

**Main effect between conditions**

| Time and direction | F-value | Sig. |
|---|---|---|
| *10 sec. anterior-posterior sway* | 209.581 | 0.000* |
| *20 sec. anterior-posterior sway* | 267.404 | 0.000* |
| *30 sec. anterior-posterior sway* | 303.641 | 0.000* |
| *10 sec. Lateral sway* | 195.891 | 0.000* |
| *20 sec. Lateral sway* | 239.936 | 0.000* |
| *30 sec. Lateral sway* | 247.95 | 0.000* |

*.The mean difference is significant at the .05 level.

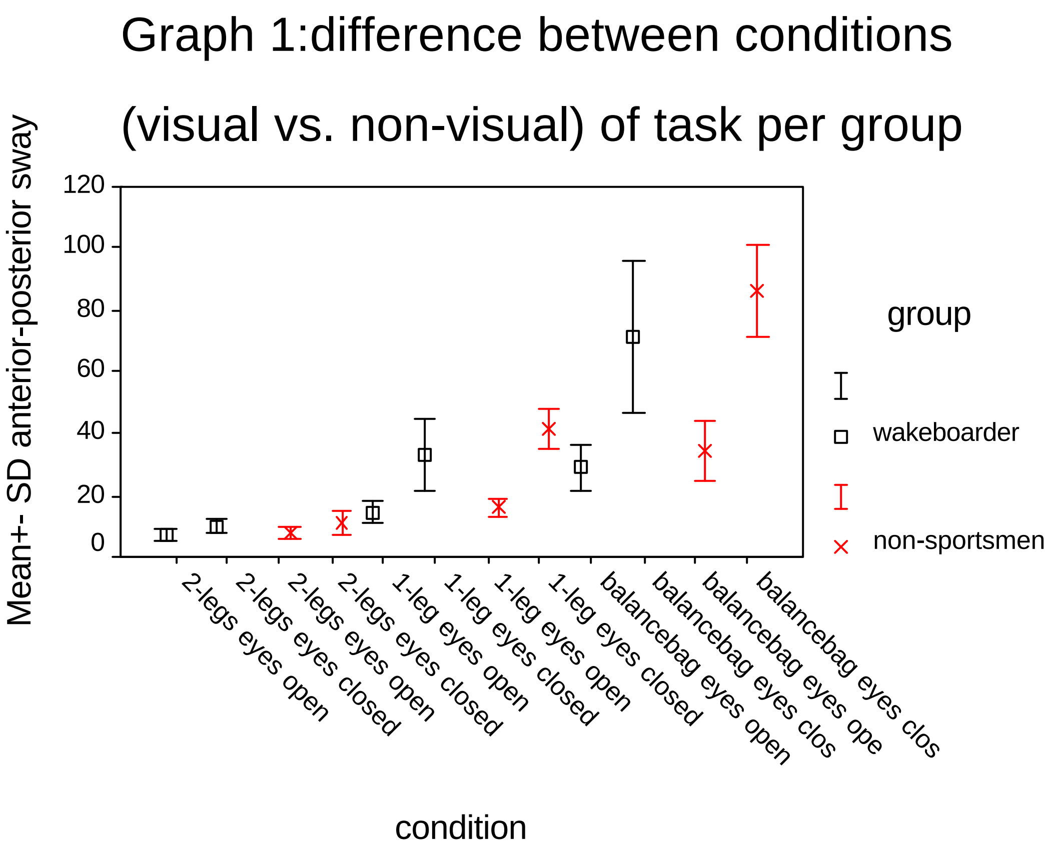
Table 6

**Interaction between group and condition**

| Time and direction | F-value | Sig. |
|---|---|---|
| *10 sec. anterior-posterior sway* | 2.925 | 0.014* |
| *20 sec. anterior-posterior sway* | 3.297 | 0.007* |
| *30 sec. anterior-posterior sway* | 3.251 | 0.007* |
| *10 sec. Lateral sway* | 1.654 | 0.147 |
| *20 sec. Lateral sway* | 2.309 | 0.045* |
| *30 sec. Lateral sway* | 1.886 | 0.097 |

*. The mean difference is significant at the .05 level. .

The post hoc test used to explore the relationship between visual vs. non-visual revealed no significant difference when the wakeboarders and non-sportmen group performed the bipedal task. No change was observed over time, as the level of significance was constant at 1.000. A similar result was found for all directions of sway for each group (graph 1). A significant difference was found between the visual and non-visual conditions during the unipedal and balance bag task in both the wakeboarding and non-sportsmen group in the anterior-posterior and lateral direction over every ten-second period.




The post hoc test also revealed that there was no observable significant difference in the cumulative magnitude of variation of postural sway between wakeboarders and non-sportsmen when they were compared on the same task in the lateral direction over time. This was also the case in the anterior-posterior direction with one exception. When wakeboarders were compared to non-sportsmen on the balance bag without visual information a significant difference (p = 0.016, 0.014, 0.017) was found, and this was maintained over time (table 7). The wakeboard group performed better on the balance bag without visual information then the non-sportsmen,

Table 7.

**Comparing two groups on a task per condition over time.**

***Level of significance between groups on a task per condition over time.***

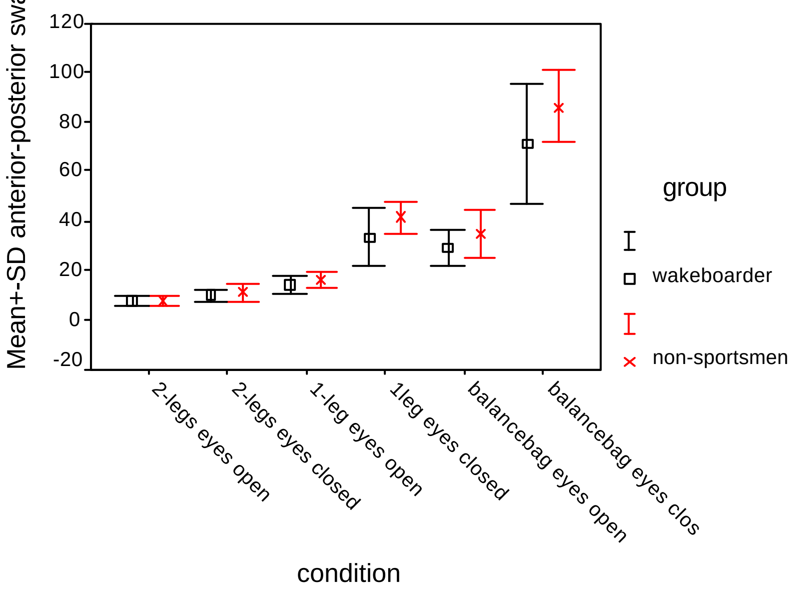
| | Anterior- Posterior | | | Lateral | | |
|---|---|---|---|---|---|---|
| ***Time*** | 10 sec. | 20 sec. | 30 sec. | 10 sec. | 20 sec. | 30 sec. |
| ***Bipoldal visual*** | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| ***Bipedal non-visual*** | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| ***Unipedal visual*** | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| ***Unipedal non-visual*** | 0.587 | 0.724 | 0.809 | 0.746 | 0.815 | 0.811 |
| ***Balance Bag visual*** | 0.903 | 0.982 | 0.991 | 0.996 | 1.000 | 0.999 |
| ***Balance bag non-visual*** | 0.016* | 0.014* | 0.017* | 0.434 | 0.226 | 0.521 |

***Based on observed means.***

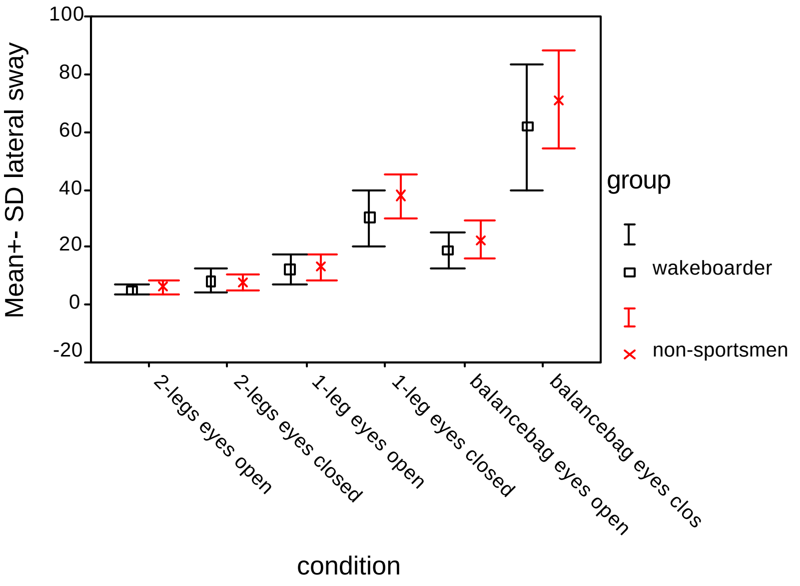
****. The mean difference is significant at the .05 level.***

A Spearman's correlation between the level of performance of each wakeboarder and the cumulative magnitude of variation of postural sway showed a significant correlation in two conditions during six specified time periods. In the anterior-posterior direction, significance was found in condition 3 (Unipedal, eyes open), for the ten second ($r = -.610$, $p = .004$), twenty second ($r = -.505$, $p = 0.023$) and thirty second ($r = -.536$, $p = .015$) time period. The lateral direction showed a significance in condition 2 (Bipedal, eyes closed) for the ten second ( $r = -.524$, $p = .018$) and twenty second ($r = 0.487$, $p = 0.029$) time period and in condition 3 for the twenty second ( $r = -.396$, $p= .084$).

Graph 2:Anterior-posterior sway after 30 s




Graph 3: Lateral sway after 30 s



## Discussion and Conclusion

Regarding our first hypothesis the study demonstrates that wakeboarders have a significant better general sense of balance than non-sportsmen in both directions when only the groups are compared. When conditions were taken into account a significant difference between the groups could constantly be found in anterior posterior direction but not in lateral direction. According to these results, a transfer of motor ability in the performance of balance by wakeboarders compared to sedentary subjects during all conditions only took place in the anterior-posterior direction.

There are two leading theories in the context for the transfer of motor abilities. Adam's (1987) general motor ability hypothesis suggests that any human skill should remain observable among various tests. This theory is supported by research of Kioumourtzoglou et al. (1997) who found that elite groups of gymnastics performed better in static balance tasks than control groups. Contrary to Adam's general motor ability hypothesis is Henry's theory that predicted that transfer among skills should be quite low because motor ability is specific to a particular task. The study of Hugel et al. (1999) supports this hypothesis, the authors concluded that there was no automatic transfer of balance skill in classically trained ballet dancers. Transfer can only occur if the tasks being performed are made sufficiently difficult as reported by Lin et al. (2000) and Vuillerme et al. (2001a). The current study took this into account and the increased difficulty was demonstrated by the high number of falls, especially in the control group. The current study showed a transfer of motor skill in the anterior-posterior balance but no transfer in the lateral balance, indicating that the transfer of balance in a certain direction of the sway may be more specific to a particular task or to the amount of difficulty of the task. The performance of the wakeboarders on each of the separate conditions did not differ significant from that of the non-sportsmen, the main exception was the condition involving the balance bag with eyes closed where a significant difference between the groups was noted. This condition could be seen as task specific, because standing on a balance bag may be comparable to the dynamic conditions involved in wakeboarding. A possible "ceiling effect" could be present for the easy tasks, a possible transfer could then not be seen. Results of this current study could be used to support either Henry's or Adams' theory. A weak transfer of balance skills seems present.

For the second hypothesis the results imply that for both groups visual information became more important for maintaining balance as the tasks became increasingly difficult. In both the wakeboard and the control group a significant difference was found between visual and non-visual conditions, leading to the conclusion that visual information is an important factor for maintaining balance. A similar result was found for the bipedal tasks in the study of Hugel et al. (1999). They found no significant effect on the postural balance between dancers and non-dancers in the absence of vision.

A significant effect between visual and non-visual conditions was found on maintaining balance during the unipedal task and the balance bag task. These results support the findings of Day et al.(1993), who found that the dependence on visual information for maintaining balance increased during increasing stance difficulty. Wakeboarders were significantly better in maintaining balance on the balance bag without visual input than the non-sportsmen.

The performance of the wakeboarders on each of the separate non-visual conditions did not significantly differ from the non-sportmen except under one condition. A significant difference between both groups was observed in the performance on the balance bag with eyes closed. A possible explanation is provided by the findings of Inglis et al. (1995), whose results indicated that although the vestibular system may be important for maintaining balance during fast dynamic movements, it plays a lesser role in static postures. The balance bag clearly required a better sense of dynamic balance. Wakeboarders move over a constant changing surface in combination with high speed and varying environmental conditions such as wind and rain. It is therefore possible that wakeboarders train another system that is less involved during static balance. This leads to the conclusion that wakeboarders maintenance of dynamic balance might depend more on vestibular and somatosensory sources, than that of the control group.

A correlation between wakeboarder performance level and the amount of variation of postural sway in different conditions during increasing task difficulty, was only found in six of the 36 possible combinations formed by condition, direction of sway and time period. This was in contradiction to the third hypothesis. In general no relation between the level of performance of the wakeboarder and the dependence on visual information for maintaining static balance during increasing task difficulty was found. Thus the required skill for maintaining balance during static balance tasks did not depend on the skills required to be a good wakeboarder.

The results showed no direct evidence for an automatic transfer of the balance skill of wakeboarding to different static balance tasks. Nevertheless, the wakeboarders performed better in the anterior-posterior direction of the sway. Visual information is a major input for balance control and the importance of visual information for maintaining balance is increased as the tasks became more difficult. However, wakeboarders seem to rely less on the visual system than non-sportsmen. This indicates they might have learned to rely more on other systems than the visual system to control their balance.

When the experiment was conducted subjects were physically not at their best. One participant of the expert group reported pain in the right ankle under condition 6 and three participants used narcotic substances the night before. The subjects were not excluded from this study because they declared that the narcotic substances or the pain did not diminish their wakeboarding skills on the day of measurement. The after effect of these substances could have had an influence on the current results. Another limitation of the study was that a number of subjects lost their balance during the experiment and fell off the force platform, before they had reached the 30 second time limit. In order to include their data in the statistical analysis the current study chose to use a penalty system, in which a percentage was added to the worst cumulative variation of postural sway in the direction of movement. This means that results are artificially manipulated. However, the number of times a subject fell off is a ranking of performance. The current study also did not divide the wakeboarding group into categories (motorboat, cable and kite). Future research could measure if there is any noticeable difference between motorboat/cable wakeboarding and kiting.

In conclusion, the present findings suggest that balance skills required for becoming a better wakeboarder are task specific and that these are not strongly transferred to other tasks. Such a finding implies that to become an expert in wakeboarding participants must train and develop task specific skills. Visual information is a major input for balance control and the importance of visual information for maintaining balance is increased as the tasks become more difficult.

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