Regulation of Balance After Spinning: A Comparison Between Figure Skaters and Controls

Cadence M. Baker¹, Gordon E. Barkwell¹

¹Department of Health Studies, Western University

No conflicts of interest declared.

Abstract

Introduction: The purpose of the present study was to compare the balance performance of control subjects and varsity figure skaters after spinning on a turntable for 6 seconds. It was hypothesized that figure skaters would demonstrate better balance control after spinning.

Methods: 9 female figure skaters and 9 female control subjects stood as still as possible for 15 seconds on a Kistler force plate during both a control condition and after spinning for 6 seconds on a turntable. Balance performance was quantified by the percentage of total time the center of pressure (CoP) was within a 5mm radius of the center of their base of support (BoS).

Results: In the control condition, figure skaters and control participants did not have significantly different balance ability. In the post-spin condition, figure skaters were significantly better at maintaining their CoP within a smaller area.

Conclusions: These results are valuable from a training and coaching perspective because they suggest that balance performance after spinning can be improved with training.

Introduction

Balance is the adjustment of the body to prevent falling, and is important in daily tasks as well as for sport performance (1). It is divided into two subcomponents: dynamic and static balance (2). Dynamic balance involves movement of both the centre of mass (CoM) and the base of support (BoS) (3). Static balance involves movement of the CoM, while the BoS remains stationary (3). “Quiet standing” is often used in a laboratory setting to study static balance performance, and typically involves participants standing with their feet side-by-side, as still as possible (1). Balance is often evaluated by analyzing movement of the centre of pressure (CoP), defined as the point of application of the ground reaction force vector (1).

The vestibular system is highly involved in balance regulation; it enables the vestibulo-ocular reflex (VOR) (4) and provides information on linear and angular accelerations of the head through movement of fluid in the inner-ear (5, 6). The VOR allows a stable image to form when the head is moving, which is important to balance regulation (4). Linear accelerations are sensed by the utricle and saccule, while angular accelerations are sensed by fluid movement in each of three semicircular canals (one semicircular canal for each rotational axis: x, y and z).
Fluid movement caused by head motion stimulates cilia, small projections in the canals, which send information to the brain about movement (7). Dizziness occurs after spinning rapidly because the fluid in the semicircular canals continues to move, even though the body has stopped. Thus, the cilia continue to be stimulated, providing mismatched information: the visual system indicates that the body is stationary while the vestibular system indicates that the body is spinning (6).

Figure skating requires strength, flexibility, and balance (8). In typical performances, athletes experience periods of rapid spinning. Additionally, figure skates provide a small BoS, which challenges balance performance (9). Despite this, figure skaters are generally able to maintain balance throughout their performances. Results from a 4-week office conditioning program have previously demonstrated that figure skaters can improve their balance with training (8). However, spinning was not specifically addressed in that study.

In competition and training, figure skaters tend to spin in only one direction. Unidirectional rotation produces asymmetrical vestibular habituation in animals (10) and gymnasts (11). However, these results don’t hold in figure skaters; symmetrical vestibular habituation has been observed with training, regardless of spin direction (4).

Previously, static posture has been compared between synchronized figure skaters and control participants (12). Figure skaters had better balance than control participants when standing on a pliant surface which caused postural disturbances (12). Additionally, figure skaters demonstrated better weight distribution when standing on a pliant surface, which was thought to reproduce the unsteady condition of skates on ice (12). To our knowledge, no previous work has directly measured changes in balance performance before and after a period of high-velocity spinning. Since figure skaters regularly perform high-velocity spins during their training, replicating this condition in a lab setting may provide more direct information on how their balance performance changes by comparing them to a physically similar group of untrained individuals.

The purpose of the present study was to examine the different effect spinning had on balance performance in control participants versus figure skaters. It was hypothesized that figure skaters would display better balance performance than control participants after a period of rapid spinning. It was further hypothesized that balance performance would not differ between groups in the control (“no spin”) condition.

Methods

Participants

This study was approved by the University of Western Ontario’s Health Sciences Research Ethics Board, and all participants provided written informed consent. All participants were females between the ages of 18 and 22 years. Participants were excluded if their body mass was larger than 68 kg. This was because they were spun using a mass that was proportional to their body mass, and we could not safely use masses larger than 17 kg. Figure skating participants were required to be actively training (training a minimum of six hours per week) at the time of the study. Twenty-three female participants were recruited to participate in the present study by posters which were displayed outside the ice rink locker rooms and in Thames Hall (an academic building at Western University). Twelve control participants and eleven varsity figure skaters volunteered. All participants were undergraduate students at the University of Western Ontario. Five participants needed to be excluded from the data analysis; four due to corrupt data files, and one due to having a body mass of over 68 kg. Data from nine figure skaters and nine control participants were analyzed.

Protocol

Participants were tested under two conditions: 1) a control condition where they stood as
still as possible for 15 seconds, looking at a tape “X” on the wall in front of them with their arms at their sides and their feet shoulder-width apart (Figure 1), and 2) an experimental condition where participants were spun on a turntable at for six seconds (while seated, to ensure safety), reaching an average angular velocity of 450°/s (Figure 2) prior to balancing. Six seconds was selected as the timeframe for spinning during a pilot experiment as they began to slow noticeably after six seconds. All balance trials were 15 seconds long and involved standing as still as possible on a force plate, with their arms at their sides and their feet shoulder-width apart, while looking at a tape “X” on the wall in front of them. This test duration is long enough to be reliable (13, 14), and short enough so that the effects of the spinning would be captured. All testing was performed in a quiet room with no visual or auditory distractions. Participants were given the option to specify their spin direction since figure skaters usually train by spinning in one direction. The order in which participants performed the tests was pseudo-randomized (participants with an even numbered study code performed the control first, and those with an odd study code performed the experimental condition first). A minimum two minutes of rest was provided between tests and it was clarified with participants that they were not dizzy before starting the next test.

**Equipment**

One piezoelectric force plate (9287B, Kistler Holding AG, Winterthur, Switzerland) was embedded in the floor of the lab. Voltage signals from the force plate were amplified (AMP 9865C, Kistler Holding AG, Winterthur, Switzerland), sampled at 100 Hz using a 16-bit analogue-to-digital conversion board (779407-01, National Instruments, Austin, TX, USA), and recorded with a custom LabVIEW program (Version 10.0, National Instruments, Austin, TX, USA).
Participants had different body masses, and therefore different moments of inertia when seated on the turntable. To account for these differences, a pulley system was used to spin participants. At one end, a rope was wrapped around the turntable. At the other end, 25% of the participant’s body mass was suspended at a height of 2 m and then released (Figure 2). This effectively applied an equivalent torque to the turntable for all participants and resulted in a similar angular velocity between participants after the torque was no longer applied (approximately 450°/s). This peak angular velocity decreased over time due to friction, but remained relatively high for the first 6 seconds.

**Analysis**

Voltage values were converted to forces and moments using customized LabVIEW software (Version 10.0, National Instruments) that implemented equations specific to the Kistler equipment. These data were processed in Microsoft Excel (Version 2013) to calculate CoP coordinates according to routine formulae (15). The percentage of time spent by the CoP in each of 8 rings (increasing by 5 mm in radius each, as described by (16)) was calculated and compared between controls and figure skaters using unpaired t-tests. Better balance performance was defined as maintenance of the CoP within a smaller area.

**Results**

There was no significant difference in balance performance in the control condition between figure skaters and control participants (p=0.64) (Table 1, Figure 3a). Compared to the “no spin”

<table>
<thead>
<tr>
<th>Ring #</th>
<th>Control Pre Spin</th>
<th>Control Post Spin</th>
<th>Figure Skater Pre Spin</th>
<th>Figure Skater Post Spin</th>
<th>Average % time in ring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73.04</td>
<td>42.48</td>
<td>77.24</td>
<td>68.66</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>24.61</td>
<td>32.45</td>
<td>26.39</td>
<td>31.88</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.08</td>
<td>12.63</td>
<td>2.75</td>
<td>5.70</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.27</td>
<td>4.96</td>
<td>0.53</td>
<td>1.24</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.00</td>
<td>3.00</td>
<td>0.13</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.00</td>
<td>2.04</td>
<td>0.19</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td>1.11</td>
<td>0.17</td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.00</td>
<td>0.46</td>
<td>0.18</td>
<td>0.33</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Percentage of total time spent with the participant’s CoP in a 5mm radius from the centre of their BoS. * significantly different between experimental groups at p<0.01. † significantly different between conditions in the same experimental group.

**Figure 3:** A) excursions of CoP of one representative control, and figure skating participant in control condition. B) excursions of CoP of the same representative control, and figure skating participant after spinning for 6 seconds.
condition, both control and figure skating participants were less able to maintain their CoP within a 5 mm radius after spinning according to a one-tailed, paired t-test with alpha set to 0.01 (p=0.003 and p=0.007, respectively). After spinning, figure skaters displayed significantly better maintenance of CoP within a 5 mm radius compared to controls (p=0.003) (Table 1, Figure 3b).

Discussion

The purpose of this study was to examine the differences in standing balance between figure skaters and controls after a period of spinning. It was hypothesized that the standing balance of figure skaters would be less affected by spinning than the control participants. Represented by a larger percent of time spent by the CoP in a 5 mm radius from the center of their BoS.

The results of the present study supported our hypothesis; figure skaters were able to maintain their CoP within a smaller range than control participants after spinning. This was likely due to their training, which enabled them to adapt to extreme postural disturbances, such as spinning at a high angular velocity. Since balance is regulated by a collaboration of several different feedback systems, there are many possibilities for adaptation.

In a previous study, figure skaters who completed a period of training which involved manipulations to BoS size and surface stability demonstrated a decreased CoP path length during a static balance task (8); this demonstrated that the neuromuscular system could be trained to more tightly regulate balance when the BoS is compromised. Improved balance performance has also been observed following training which involved exposure to a rotating visual reference (a room which spun around stationary participants) (17). Participants demonstrated greater ability to maintain their CoP within a smaller area after this intervention (17). While these participants were not figure skaters, the findings are directly applicable to spines that figure skaters perform; figure skaters look straight ahead with their eyes open when spinning, which is a very similar visual stimulus to a rotating room. Trainability of the vestibular system in figure skaters has also been demonstrated in a study where participants experienced various stimulations of the vestibular system without vision (4). After nausea stimulation (a spinning condition designed to induce motion sickness), figure skaters displayed significantly less motion sickness symptoms than controls (4). This indicated figure skaters were better able to cope with the sensory mismatch which occurred after spinning (6). The VOR, or adjustment of eye movements to create a stable visual image, has also been examined in past studies (4). Eye movements of figure skaters were more tightly controlled both during and after the spin, thus allowing them to form a more stable image and establish a visual reference system (4). It was further noted that figure skaters showed habituation from a young age when they trained regularly, demonstrating that the three balance systems can be trained (4). Overall, these studies have demonstrated the trainability of three separate balance regulation systems, any of which could explain the results of the present study. Similar results have been observed with synchronized figure skaters, who did not have significantly better balance than control participants during quiet standing on a firm surface with eyes open (12).

The present study did not find a significant difference between the balance abilities of control and figure skating participants in the “no spin” condition. This indicates that figure skaters do not necessarily have better balance than control participants in everyday conditions, but are better able to regulate balance after spinning. This provides further evidence for the specificity of a figure skater’s training, which prepares them to remain in control of balance following rapid spins.

Limitations

The present study had several limitations. The current study evaluated quiet standing, a form of static balance, while competitive figure skating
involves dynamic balance. Accordingly, these findings may not carry over to a dynamic balance scenario. While the present study demonstrated a clear improvement in balance due to training with high-velocity spins, it could not determine which balance regulation system contributed to this difference. Finally, the present study spun participants in a seated position due to safety concerns. This position may not be representative of figure skating technique, as figure skaters spin while standing upright. Accordingly, the findings in this paper may not be representative of the upright standing condition in figure skating.

Future Directions

Future research should include participants with a broader range of ages, as well as both sexes to determine if results differ across these populations. A motorized turntable may also be used in future studies, which would turn all participants at a more precise angular velocity. This turntable should also be positioned adjacent to the data collection equipment to minimize delay between spinning and balance measures. It may also be beneficial to remove the contribution of one or more balance regulation systems (such as vision by blindfolding the participant) in order to isolate the effects of repeated spins on each system. The turntable may also be modified to allow participants to spin while standing upright by incorporating a safety harness. Since dynamic balance is more applicable to a figure skating scenario, future studies may consider evaluating dynamic balance with video or infrared motion analysis systems in order to better understand movement of the entire body, and not only ground reaction forces.

Conclusions

In conclusion, figure skaters maintained their CoP within a smaller range after spinning than control participants. This was likely due to their training, which involved repeated spinning at high angular velocities and resulted in adaptations to their balance regulation systems. By evaluating balance after spinning, we have provided information which is more directly applicable to a figure skating scenario. Since spinning is a regular occurrence in the sport of figure skating, the findings of this experiment are important from a training and performance perspective. In a performance, it is important that a figure skater displays good balance after spinning as typical choreography does not allow time to regain balance after spinning. From a training perspective, these results are of interest because they suggest that balance performance after spinning can be improved with training.

Acknowledgements

This project was completed as part of the course requirements for Kinesiology 4520, Clinical Biomechanics. We would like to thank Dr. Jim Dickey, Shaylyn Kowalchuk, Jeff Brooks and Sasha Guay. Without your assistance and expertise this project would not have been possible. We would also like to extend our thanks to all volunteer participants. Both authors contributed equally to this manuscript. Names are listed alphabetically.

References:


WURJ: Health and Natural Sciences Vol.7 Issue1 http://dx.doi.org/10.5206/wurjhns.2016-17.1