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# Does movement proficiency impact on exergaming performance?

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ABSTRACT

There is growing interest in the use of consumer level exergames in movement skill acquisition. The purpose of this study was to investigate the relationship between movement proficiency and performance in virtual exergaming. Twenty seven children, aged 10–15 years participated in an experiment completing the Movement Assessment Battery for Children 2 (MABC-2) and a series of XBOX360 Kinect Sports exergaming tasks. Significant correlations were observed between MABC-2 aiming and catching percentile and exergame javelin and target kick, where the more proficient movers tended to perform better in the exergame. Statistically significant correlations were observed between MABC-2 balance percentile and exergaming sprint and target kick performance. In this study children who scored better in real life gross motor movement tasks performed better in most related exergaming activities. This suggests current exergaming technology has advanced to a point where body movement unencumbered by a physical or remote game device tether can extract movements resembling real life tasks, translate them into game play and reward proficient movers with higher in-game performance. It is possible that benefit gained in an exergaming environment by more proficient movers was a result of either their more proficient movement, or a greater ability to adapt to the exergame.



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## 1. Introduction

Exergames (active games, active video games, Xergames) are interactive games which, in contrast to traditional sedentary electronic games, require active body movement (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008; Deutsch et al., 2011; Lieberman et al., 2011; Mears & Hansen, 2009). There has been growing interest in the relationship between consumer level exergames and cardiovascular health (Mills et al., 2013) and movement skill acquisition (Fery & Ponserre, 2001) in educational settings (Fiorentino & Gibbone, 2005; Hayes & Silberman, 2007; Lieberman et al., 2011; Papastergiou, 2009; Sheehan & Katz, 2010) and in populations with movement dysfunction (Straker et al., 2011). Exergames use one, or a combination of 2 dimensional and 3 dimensional motion capture devices such as hand held haptic sensor-based remotes or foot pads, kinetic force plates, and light sensors (Deutsch et al., 2011; Levac et al., 2010; Lieberman et al., 2011; Mears & Hansen, 2009). The Microsoft Kinect (XBOX360) system utilises 3D depth cameras to capture 3D motion (Zhang, 2012). Through this technology, real environment movements are translated to virtual environment movements where the player is represented within the game as an avatar (Deutsch et al., 2011). There is debate as to whether exergaming may be a useful means for developing fundamental movement skills (FMS) (Barnett, Hinkley, Okely, Hesketh, & Salmon, 2012), which are the foundation movements that form the basis of more complex and sport specific motor skills (Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Okely & Booth, 2004). While research has shown a consistent positive association with increased FMS proficiency and higher levels of physical activity and increased sport participation (Lubans et al., 2010; Okely & Booth, 2004; Okely, Booth, & Patterson, 2001; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006), there is currently little evidence regarding the relationship between FMS proficiency and exergaming to progress this area of research (Sheehan in Katz & Clyde, 2012).

Previous work has documented a partial list of fundamental movement skills used in a select range of exergames for development of physical literacy (Sheehan & Katz, 2010), and has aligned movement skills with specific components of Wii Fit and Wii Sport in a rehabilitation context (Deutsch et al., 2011). The compendium by Deutsch and colleagues (2011) aligns the required use of balance, coordination, endurance, strength (cardiovascular and neuromuscular), and upper extremity control (unimanual and bimanual) skills in components of each Wii Fit/Sports game for ease of game selection by clinicians for beneficial exergame prescription. They did not assess movement proficiency, however, they provide a basis on which further research can expand. Barnett and colleagues (2012) investigated the relationship between fundamental movement skill proficiency and the amount of time spent in interactive and non-interactive gaming among preschool children. They found that children who spent more time playing interactive (i.e. Wii) electronic games performed better in the assessment of object control skill, however, no association was observed between interactive electronic gaming time and locomotor skills. One study that examined the link between video gaming and laparoscopic skill used three Nintendo Wii games that had movement patterns similar to those required in laparoscopic tasks (Badurdeen et al., 2010). The significant positive correlation observed between Wii and laparoscopic task performance suggests movement proficiency may extend into virtual reality with more proficient movers being rewarded in an exergaming environment. To the authors' knowledge, no research has been undertaken to examine the relationship between fundamental movement skill proficiency and exergame success.

The limited research that has been conducted on fundamental movement skills and movement patterns in commercial exergaming suggests that movement during gaming is highly varied (Levac et al. 2010; Pasch, Berthouze, van Dijk, & Nijholt, 2008; Pasch, Bianchi-Berthouze, van Dijk, & Nijholt, 2009). The required use of fundamental movement skills and movement patterns are dependent on the game activity, such as throwing, kicking or jumping and on whether full body movements or simple wrist movements to manipulate a remote are required to achieve the goals of the activity. Movement patterns both within and between exergames vary widely for individuals and between participants to achieve the same goals within exergaming contexts (Levac et al., 2010; Pasch et al., 2008, 2009). Levac and colleagues (2010, p. 1025, 1029) employed four Wii and Wii Fit exergames to determine whether children's movement quantity and quality differed between trials of the same game, between different games or between player experience status (non-experienced or experienced). A wide range of participant movement strategies both within and between games was identified. While experience did not significantly affect quantity of movement, different movement patterns and quality of movement were observed, with more experienced gamers showing higher quality of movement compared to non-experienced gamers (Levac et al., 2010). Levac and colleagues (2010, p. 1036) note that given the variation of movement required and observed, research should be undertaken to 'explore the relationship between movement and factors such as ... real life sports experience/activity, and game success'.

Given the amount of variation observed in the use of, and performance of movement skills and patterns, further research is required to investigate whether those who are proficient movers in a real physical environment are benefited in an exergaming environment. If proficient movers are rewarded with higher performance scores when playing Microsoft Kinect games, then there is potential to exploit the Kinect technology to compliment skill development (Papastergiou, 2009). Positive transfer effects have been demonstrated in rehabilitation (Abdel Rahman & Shaheen 2011; Plow et al. 2011; Shih, Shih & Chu 2010; Vernadakis et al. 2012) and motor skill development (Fery & Ponserre, 2001) studies. Therefore, these games might be appropriate for increasing both physical activity and skill acquisition. Whilst exergaming is not a substitute for sport and other forms of physical activity (Daley, 2009; Graves, Stratton, Ridgers, & Cable, 2008), this field is of increasing relevance as levels of sedentary behaviour and screen based activities are rising alongside a decline in physical activity levels (Graves et al., 2010). The purpose of this study is to investigate the relationship between movement proficiency in real physical and virtual exergaming environments when individuals are aiming to do their best during game play.

## 2. Methods

### 2.1. Participants

Twenty seven children, 16 boys and 11 girls aged between 10–15 years (M = 12 years 6 months, SD = 1 year 7 months) were recruited from the local community after responding to printed and word of mouth advertising. Both experienced and novice exergamers were included in the study population, with the only exclusion criterion being participation in XBOX360 Kinect Sports Track and Field and/or Kinect Sports Football in the previous three months. Participants played an average of 78.65 min of electronic games per week (range: 0–330 min, SD: 87.90). Data was missing for one participant. Participants and their legal guardians provided informed consent for inclusion in the study, which was approved by the University of Western Australia Human Ethics Committee.

### 2.2. Procedure

Participants completed the Movement Assessment Battery for Children 2 (MABC-2) and an exergaming session (XBOX360 Kinect Sports) in a randomised order. All testing was performed in the School of Sports Science, Exercise and Health Exergaming Laboratory at The University of Western Australia.

#### 2.2.1. The Movement Assessment Battery for Children 2

The MABC-2 comprises a series of motor tasks which are separated into three components: manual dexterity, aiming and catching and balance. Scores are calculated for each component of the test and for the combination of the three components which are then converted to age-standardised scores and

**Table 1**
Manual dexterity, aiming and catching, balance and total MABC-2 percentile scores.

| | | Manual dexterity percentile | Aiming and catching percentile | Balance percentile | Total MABC-2 percentile |
|---|---|---|---|---|---|
| MABC-2 | Min | 1 | 16 | 9 | 5 |
| | Max | 75 | 99 | 91 | 98 |
| | Median | 16 | 91 | 50 | 50 |
| | SD | 21.13 | 22.80 | 29.70 | 26.72 |

**Table 2**
Description of XBOX360 Kinect Sports Exergaming Activities and hypothesised relationship with components of MABC-2.

| | Sprint | Javelin | Long jump | Discus | Hurdles | Target kick |
|---|---|---|---|---|---|---|
| Description of activity | Participants run on the spot to move their avatar along a straight running track | Participants reach to their preferred side to pick up a javelin. A short run up followed by a javelin throw. Participants are cued to throw by the changing ground colour | Participants run on the spot to move their avatar along the run up and jump when cued by the ground changing from red to yellow, and to green | Participants reach to their preferred side to pick up a discus. The discus is thrown from a stationary position | A running track with four hurdles to jump over at intervals. Participants run on the spot and at the hurdles are cued to jump by the changing ground colour | Kicking and aiming at targets in a football goal guarded by a goal keeper. The aim is to knock down as many targets as possible. Targets refresh when all targets are removed |
| Rationale for inclusion | Running is a locomotion fundamental movement skill. The task requires the use of dynamic balance which is incorporated in the MABC-2 balance component | Throwing is an object control a fundamental movement skill. The task requires the use of throwing which is incorporated in the MABC-2 aiming and catching component | The long jump run up and jump requires the use of balance which is measured in the MABC-2 balance component | Exergaming discus does not mirror a throw. Discus was included as an activity which does not require the use of the movement components assessed in the MABC-2 | Hurdles incorporates the use of balance for running and jumping. Balance proficiency is assessed in the balance component of the MABC-2 | Target kick requires balance for kicking and aiming to hit targets. Aiming and balance are incorporated in the aiming and catching and balance components of the MABC-2 |
| Movement required for game success | Running on the spot with high knees | Running with high knees until and throwing arm movement slowly moving a straight arm from low to high at the last point of the green area in run up | Running on the spot with high knees for the run up, and jumping high throwing both hands forwards at the last point of the green area in run up as close to the plate as possible | Starting with the throwing arm back while standing at the front of the ring. Take a step forward while swinging through high to release the discus. Move the arm back and pause before swinging forwards | Running on the spot with high knees and jumping in the green area to clear hurdles. Performance is best when running is not paused when the participant lands from the jump. Players slow when hurdles are hit | A kicking action aiming at the targets to knock targets out quickly and receive time bonuses. Goal keeper stays in front of target when only one remains. A ball kicked away from the target moves the goalie away |
| Amount of variability in task condition | The course stays the same from trial to trial. Players played alone rather than against the computer so no opponent variability was incorporated | The course stays the same from trial to trial | The course stays the same from trial to trial | The course stays the same from trial to trial | The course stays the same from trial to trial. Players played alone rather than against the computer so no opponent variability was incorporated | Variability in response to participant. Goal keeper moves according to where the ball is kicked. More time is added when targets have been knocked out, enabling a higher number of targets to be knocked down |
| Game duration | Approximately 10 sec per sprint | Each throw inclusive of the run up is approximately 5 sec | Each attempt inclusive of the run up is approximately 5 sec | A discrete throw. | The score reported is the time in seconds taken to run the length of the course | Extra time added when all targets have been eliminated. Forty is provided to start |
| Score | The score reported is the time in seconds taken to run the length of the course | The score reported is the distance in metres the javelin travels | The score reported is the distance in metres the player jumps | The score reported is the distance in metres the discus travels | The score reported is the time in seconds taken to run the length of the course | The number of targets which are hit. |
| Hypothesised correlations | Balance proficiency | Aiming and catching proficiency | Balance proficiency | None | Balance proficiency | Balance, aiming and catching, and total MABC-2 proficiency |

percentile rank (Henderson, Sugden, & Barnett, 2007). Participants were tested on the MABC-2 (Henderson et al., 2007) by an experienced movement assessor.

Table 1 shows the range in movement proficiency measured using the MABC-2. Two participants fell below the 15th percentile, 7 between the 16th–25th percentile, and 18 in the 26th percentile and above.

*2.2.2. Exergaming session*

The exergaming session comprised six XBOX360 Kinect Sports activities: sprint, javelin, long jump, discus, hurdles and target kick. Table 2 provides a summary of the included activities. The duration of the exergaming session was approximately 45 min. Participants chose an avatar from the guest avatar selection, all of which have the same ability level in the game. Participants were familiarised with the games for 10–15 min prior to testing which involved completing the Kinect Sport Track and Field Pentathlon and the target kick mini game where they completed one round of each activity (three attempts in the one for javelin, long jump and discus). A short demonstration of each task was provided using the inbuilt game instructions so that players knew how to undertake each exergaming activity. Additional information on how to achieve better scores (e.g. running with high knees) was not provided. A brief familiarisation period was used to minimise the learning effect. All participants were randomly assigned an order in which to complete the six exergaming activities. A three level order was used by grouping games into time, distance and hitting targets outcomes. Each exergaming activity was undertaken three times in a row prior to moving onto the next activity. The games were presented in a continuous manner with participants allowed to take small breaks between tasks if required to have a drink of water or a short rest. Participants were all provided with the instruction to do as best they could for all activities and to use their dominant arm for throws. Participants were encouraged during exergaming to try to get the furthest distance, fastest time or highest number of targets they could and to try to surpass their previous scores.

### *2.3. Data collection and analysis*

The participant's score for each attempt during the testing period was recorded. Time (sprint and hurdles) was measured in seconds, distance (javelin, long jump and discus) in metres and targets (target kick) as the number of targets knocked out. Foul jumps and throws counted by the exergame were recorded as zero. The sum of the scores for the three attempts for each exergaming activity was calculated for each participant.

Spearman's Rho bivariate correlation was used to test for associations between the sum of the three attempts for each of the six Kinect Sports exergaming activities and the MABC-2 manual dexterity, aiming and catching, balance, and total MABC-2 percentiles. Spearman's Rho bivariate correlation was also used to test for associations between the sum of the three attempts for each of the six Kinect Sports exergaming activities and the average number of minutes that participants spent exergaming per week. Correlation coefficients (in absolute value) ranging from .00 to .30 were considered to represent little if any correlation, .30 to .50 low or weak correlations, .50 to .70 moderate correlations, .70 to .90 high correlations, and .90 to 1.00 very high correlations (Hinkle, Wiersma, & Jurs, 1998). Bootstrapping (500 replications) was performed to increase the robustness of the parameter estimates. Bootstrapping is a statistical technique that uses the data of the sample at hand to approximate the sampling distribution of the population. Typically bootstrapping involves randomly generating alternative samples from the study sample to create a large number of "phantom samples", known as bootstrap samples. Statistical analysis is then conducted on each of the bootstrapped samples (usually several hundred). While becoming more common due to computational power, bootstrapping is traditionally used with smaller study samples. (Chernick, 2011). Significance level was set at $p < .05$. All statistical analyses were run in Statistical Package for the Social Sciences (SPSS Inc., version 21).

## 3. Results

The sum of the scores for the three attempts for each exergaming activity was calculated for each participant. Higher scores for javelin, long jump, discus (metres) and target kick (number of targets), and lower scores for sprint and hurdles (sec) represent better exergaming performance. A summary of the exergaming activity scores is presented in Table 3.

A summary of the correlations between the MABC-2 manual dexterity, aiming and catching, balance, and total MABC-2 percentiles and the sum of three attempts for each exergaming activity is presented in Table 4. No significant correlations were observed between time spent exergaming per week and performance in the exergaming activities ($p > .05$).

No significant correlations were observed between MABC-2 manual dexterity percentile and any of the six Kinect Sports exergaming activities. Significant correlations of moderate strength were observed between MABC-2 aiming and catching percentile and javelin ($r_s = .501$, $p = .008$) and target kick ($r_s = .557$, $p = .003$), where the more proficient movers tended to perform better in the exergaming context. Statistically significance low to moderate correlations were observed between MABC-2 balance percentile and exergaming sprint ($r_s = -.478$, $p = .012$) and target kick ($r_s = .480$, $p = .011$). Significant low and moderate correlations were observed between the total MABC-2 percentile and javelin ($r_s = .418$, $p = .030$) and target kick ($r_s = .575$, $p = .002$).

## 4. Discussion

In this study children who performed better in the aiming and catching component of the MABC-2 performed better in two of the three exergaming activities related to aiming and catching. Children

**Table 3**
Sum of XBOX360 Kinect Sports exergaming activity scores for three attempts.

| | Sprint (sec) | Javelin (m) | Long jump (m) | Discus (m) | Hurdles (sec) | Target Kick (targets) |
|---|---|---|---|---|---|---|
| Mean | 29.60 | 135.80 | 23.75 | 123.16 | 59.88 | 102.26 |
| SD | 2.67 | 66.48 | 6.30 | 35.57 | 7.54 | 43.02 |
| Min | 25.37 | 26.00 | 7.75 | 72.57 | 49.95 | 26.00 |
| 25th Percentile | 27.55 | 93.18 | 19.40 | 91.56 | 53.80 | 70.00 |
| 50th Percentile | 29.48 | 127.64 | 24.39 | 118.98 | 58.39 | 103.00 |
| 75th Percentile | 30.59 | 178.96 | 27.71 | 146.25 | 63.22 | 132.00 |
| Max | 37.96 | 268.12 | 36.38 | 213.46 | 78.70 | 173.00 |

**Table 4**
Spearman's rho comparing movement proficiency measured by MABC-2 and exergaming performance ($n = 27$).

| | | Manual Dexterity Percentile | Aiming and Catching Percentile | Balance Percentile | Total MABC-2 percentile |
|---|---|---|---|---|---|
| Sprint | $r_s$ | .15 | −.01 | −.48 | −.10 |
| | Lower:Upper 95% CI | −.19:.56 | −.39:.41 | −.69:−.13 | −.43:.29 |
| | $p$ | .449 | .961 | .012* | .614 |
| Javelin | $r_s$ | .33 | .50 | .03 | .42 |
| | Lower:Upper 95% CI | .02:.68 | .16:.78 | −.34:.40 | .06:.71 |
| | $p$ | .092 | .008** | .866 | .030* |
| Long Jump | $r_s$ | .00 | .23 | −.22 | −.08 |
| | Lower:Upper 95% CI | −.33:.40 | −.17:.59 | −.51:.16 | −.38:.26 |
| | $p$ | .994 | .251 | .276 | .692 |
| Discus | $r_s$ | .17 | .14 | .08 | .24 |
| | Lower:Upper 95% CI | −.27:.58 | −.32:.50 | −.32:.48 | −.18:.62 |
| | $p$ | .391 | .488 | .676 | .235 |
| Hurdles | $r_s$ | −.10 | −.14 | −.17 | −.16 |
| | Lower:Upper 95% CI | −.48:.35 | −.46:.30 | −.45:.25 | −.49:.28 |
| | $p$ | .628 | .491 | .388 | .419 |
| Target Kick | $r_s$ | .22 | .56 | .48 | .58 |
| | Lower:Upper 95% CI | −.17:.59 | .16:.80 | .09:.75 | .20:.81 |
| | $p$ | .278 | .003** | .011* | .002** |

* Statistically significant value, $p < .05$.
** Statistically significant value, $p < .01$.

who performed better in the balance component of the MABC-2 performed better in two of the four exergaming activities related to balance. This suggests that current exergaming technology has advanced to a point where the use of body movement unencumbered by a physical or remote game device tether can extract movements resembling real life tasks, translate them into game play and reward proficient movers with higher in-game performance. Importantly, exergaming task performance, such as javelin throwing and target kicking, significantly correlated with the corresponding MABC-2 gross motor movement assessment components. These findings are consistent with the proposal that individuals who are more proficient in specific movement areas are more likely to perform better at specialised movement tasks which involve these foundation movements (Gallahue, Ozmun, & Goodway, 2012) and that fundamental movement skill proficiency is required for the application of these base skills to complex sport specific contexts (Gallahue et al., 2012; Magill, 2011; Stodden et al., 2008). Despite those with greater movement proficiency achieving higher scores in related game tasks, of interest, was the finding that the games selected in this study appeared to compensate for the wide range of children's movement proficiency. Whether exergames are intentionally designed in this way, if it is a limitation of the hardware and software to distinguish movement proficiency or a combination of both is currently uncertain.

For children with the potential to move well, as quantified by a standard movement proficiency test, there appears to be an advantage, at least initially, in exergame performance. For example, individuals who were proficient at aiming and catching performed at a higher level in javelin, which mirrors an overarm throw. Whilst both javelin and discus involve projectile throwing, unlike exergaming javelin, exergaming discus requires a sufficiently different arm swing movement to an overarm throw. It is therefore understandable that no correlation between aiming and catching proficiency and exergaming discus score was observed. Given time, it may be that more proficient throwers may adjust and become more proficient at this exergaming activity. Additionally, discus is not an activity that many children will have undertaken and so negative transfer from an overarm throw, for example bending an arm rather than executing an arm swing, may have been experienced. The advantage gained from having a higher level of proficiency in aiming and hand–eye coordination was also positively associated with exergaming target kick which has similar aiming requirements, however, employs the use of foot-eye rather than hand-eye coordination. Of interest is the similarity of this finding to those of Barnett and colleagues (2012), who identified a positive association between the amount of time playing interactive games and object control skills of preschool children. Furthermore, the challenge to balance control systems during exergaming sprint and target kick is reflected in the correlation of balance proficiency with more successful performance in these exergaming activities. Target kick requires balance and accuracy, mirroring a real life kicking situation with a support leg stance and kicking leg swing action. The moderate positive correlation between balance proficiency and target kick reflects research which has demonstrated that individuals who have better balance skills (Chew-Bullock et al., 2012) and better placement of support leg for stability (Katis et al., 2013; Lees, Asai, Andersen, Nunome, & Sterzing, 2010) are more proficient accurate kickers. The correlation of balance proficiency with more successful performance in the exergaming sprint activity reflects the challenge to balance control systems during running to maintain stability and prevent falling, as there are times when there is no body contact with the ground (Dugan & Bhat, 2005; Fredericson & Moore, 2005; Whitall & Caldwell, 1992; Winter, 1995). While the running action performed during exergaming (high knees while running on the spot) does not reflect natural running, balance remains an important component in the activity. Because the exergaming sprint activity does not mirror real running performance, it is possible that individuals with more proficient movement skills did not gain as great an advantage in the virtual environment.

Contrary to expectations, no significant positive interaction was observed between MABC-2 balance proficiency and exergaming hurdles or long jump, both of which incorporate running and jumping that require the use of balance to perform. Unlike the sprint run, for which there was a moderate correlation with balance, hurdles and long jump required coincidence or anticipation timing for jump take offs. Coincidence timing is a motor ability that underpins many motor skills (Magill, 2011) and is important in a large range of exergames. The only task in the MABC-2 that assesses coincidence timing is catching, however, the timing in the exergaming perceptual environment might be sufficiently abstract in nature and, therefore, require some time to become familiarised. It is possible that an individual who can catch a ball could display a negative transfer of learning from the real to the virtual environment where the temporal characteristics of the tasks are different. Timing of skill execution is important in these two activities as runners are slowed when they do not clear the hurdles and in long jump a greater distance can be jumped when the player is as close to the take off target as possible (with foul jumps occurring if they jump too late). It is possible that the importance of timing in the performance of the tasks may mask interactions with balance proficiency. The absence of an association between the locomotor long jump and hurdles tasks is again similar to the findings of Barnett and colleagues (2012). They found no association between amount of time using interactive games and locomotor skills, however, this study also incorporated games that did not necessarily incorporate full body movement.

The specificity of results suggest that the gaming software is sophisticated enough to discern movement variation rather than just movement, reflecting improvements in gaming software that have occurred since movement based games were first introduced. Whether the skill specific exergaming performance benefits associated with higher levels of movement proficiency reflect benefits gained from more proficient performance of skills in an exergaming environment, whether more proficient movers better adapted to exergaming task demands, or a combination of these remains uncertain. Further research should be undertaken to explore whether players with higher movement proficiency levels learn to adapt faster to game constraints than those who do not have as proficient fundamental movement skills. Regardless of the specific reason for the association between movement proficiency and exergaming performance, the results suggest that exergames have the potential to be a useful source of augmented feedback (for both motivation and information) during motor skill acquisition. The association was not so strong that exergames could be recommended for movement enhancement programs. However, the association also suggests that movers of lower proficiency could benefit, in particular from the motivation that feedback in this form might provide. An individual with relatively low movement proficiency appears to be rewarded more than a proficient mover with the resulting game score not achieving the heights of a proficient mover but certainly closing the gap between the individuals. One could also argue that this result diminishes the effectiveness of exergames as a useful source of augmented feedback for proficient movers.

Skill performance is not identical in real and virtual environments, which may impact the reliability of translation between real movement assessment proficiency and virtual exergaming performance. Physical strength is a factor that is not accounted for in many exergaming tasks. The absence of the need for physical strength and object manipulation when performing a javelin throw in a virtual environment is one example of how skills are executed differently and may enable individuals who lack strength to achieve proficient scores in a virtual setting. The reduced need for strength and object manipulation may remove barriers to participation for traditional modes of sport. Current movement proficiency testing batteries may therefore not be applicable in an exergaming context. The MABC-2 measures proficiency based on outcome measures, and does not take movement patterns into consideration for the final proficiency scores. As a result, it is possible that the use of the MABC-2 may have masked the level of relationship between movement proficiency and exergaming score outcomes. Testing of movement proficiency with reference to an exergaming context may need to utilise more of a movement process rather than outcome approach, and focus on specific movement components experienced during exergaming rather than specific skills and object related tasks. While it is evident that exergaming technology can discern between movers of different proficiency levels, we still do not have a clear idea as to the reasons behind why individuals who are more proficient movers tend to score better. This may be as a result of their more proficient movement, a greater ability to adapt to exergaming requirements, the technology itself, or a combination of these factors. However, such conclusions are beyond the scope of this study, with further research required to explore these relationships.

It is possible that the exergaming activities in this study were too short to allow greater distinction between exergame scores and higher movement skill proficiency. Previous work that has identified a large variation in movement patterns within and between individuals has utilised games of a longer duration (Levac et al., 2010; Pasch et al., 2008, 2009). The six Kinect Sports games were chosen as they provided a simple time, distance or number of targets scoring system and the short nature of the games mirrors a fundamental movement skill assessment where tasks are typically short in duration. The short time length also allowed for multiple attempts of each game to be completed within the exergaming session. Given the results, further research should be undertaken to explore whether greater benefit is experienced by those with higher movement proficiency during games which are longer in duration.

The large range in movement patterns that has been observed within individuals during exergaming (Levac et al., 2010; Pasch et al., 2008, 2009) may in part explain how individuals with similar movement proficiency achieved different exergaming scores. The MABC-2 is an objective and outcome-oriented measure, which does not reflect the qualitative and process-oriented aspects of a child's movement. Therefore, it is possible that children with similar MABC-2 scores could move differently to achieve those scores and it would be those differences that the Kinect detects resulting in variations in gaming score. Whilst there is a spread of movement proficiency levels within the study population, a limitation of this study is that there are a large number of participants who scored highly in aiming and catching proficiency, with only a small number having a low level of proficiency. This study was designed to assess the impact of level of movement proficiency on exergaming performance during a once off exergaming session without incorporating a learning effect. Further research should be undertaken to examine whether there is a faster or greater learning effect for how to achieve optimum performance during exergaming amongst those who are more proficient movers. Another limitation of this study, is the influence of previous exergaming experience of participants and their performance in the exergame tasks. It is plausible that participants who were more familiar with exergaming adapted more quickly to the required game task. To control for this possibility, participants who had not played Kinect Sport in the last three months were recruited, although they could have played other games. Nonetheless there appeared no influence of the average number of hours per week of exergaming on their performance in this study. Therefore, the effect of previous gaming appears to minimally impact the results of this study. While the research question addressed here was specifically related to participants' movement proficiency and its relation to exergaming performance, there was no attempt made to assess the actual movements performed while playing in the virtual environment. Future research should also address whether individuals with the potential to move well actually move well when they are exergaming or, related to the point raised previously, that they are better at attuning their movement to the environmental context placed before them.

## 5. Conclusions

Individuals who are more proficient at aiming and catching appear on average to perform better and achieve higher scores during related exergaming activities, such as javelin and target kick, than those who are less proficient. Those who are more proficient at balance appear to perform better and achieve higher scores during related exergaming activities, including sprinting and target kick. In a practical sense, however, the correlation between proficiency and performance was not so strong that individuals with lower movement skills would be discouraged from participating. Whether the small size of the benefit observed is a result of the real life movement assessment not corresponding to a gaming environment, a limitation of the gaming platform not being sensitive enough to discern or require movement proficiency, or a combination of these is uncertain. It is possible that the benefit gained in an exergaming environment by more proficient movers was a result of either their more proficient movement, or a greater ability to adapt to the exergame demands. Given the high level of variation of movement required during exergaming (Levac et al., 2010; Pasch et al., 2008, 2009), the transference of these results to consoles other than XBOX360 Kinect and other games should be done cautiously. Further research is required to explore the effects of movement proficiency during exergaming and examine the relationship between movement proficiency and long term learning effects in an exergaming context.

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