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Impact of Virtual RealityTraining on Real-World Hockey Skill: An Intervention Trial

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Abstract: Training specificity is imperative for successful performance of the elite athlete. Virtual reality (VR) has been successfully applied to a broad range of training domains. However, to date there is little research investigating the use of VR for sport training.The purpose of this study was to address the question of whether virtual reality (VR) training can improve real world hockey shooting performance. Twenty four volunteers were recruited and randomly selected to complete the virtual training intervention or enter a control group with no training. Four primary types of data were collected: (1) participant's experience with video games and hockey, (2) participant's motivation toward video game use, (3) participant's technical performance on real-world hockey, and (4) participant's technical performance in virtual hockey.One-way multivariate analysis of variance (ANOVA) indicated that the intervention group demonstrated significantly more real-world hockey accuracy ($F(1,24) = 15.43$, $p < 0.01$, E.S. = 0.56) while shooting on goal than their control group counterparts (intervention M accuracy = 54.17%, SD=12.38, control M accuracy = 46.76%, SD=13.45). One-way multivariate analysis of variance (MANOVA) repeated measures indicated significantly higher outcome scores on real-world accuracy (35.42% versus 54.17%; ES = 1.52) and velocity (51.10 mph versus 65.50 mph; ES=0.86) of hockey shooting on goal. This research supports the idea that virtual training is an effective tool for increasing real-world hockey skill.

Key words: Virtual training, hockey skill, video games, esports.

1. Introduction

The idea of expertise is an appealing topic in numerous domains, including sport. In the domain of athletics there is a continual demand for new and innovative training regimens. Professional teams employ high-level coaches, and leverage specialized equipment and technology to push the boundaries on human performance.This trend spreads beyond professional sports to youth sports as well. Often fueled by the goal to attain a college scholarship, parents will invest money and time into providing the right training for their child. There are many paths to knowledge; instruction, reading, study, and coaching. A challenge is finding an engaging and accurate source of knowledge. While a sufficient knowledge base is very important, understanding the limitations keeping a student or athlete from this knowledge is equally important. One of the biggest limitations when it comes to expertise is instructional resources. Access to a knowledgeable coach during the learning process is essential to skill development. Research has shown that time spent with an instructor is crucial to an athlete's overall development [1]. Given that a coach is normally responsible for a high percentage of an athlete's practice time, the coach's ability to devise an optimal learning environment becomes significant to an athlete's development [2].

Video games are of particular interest because they have been shown to be very effective teaching tools [3]and have potential for skill improvement [4]. Success using video games has been recorded in such diverse domains as classroom education [5], marine training [6], and certain surgical procedures. In sport, studies conducted in American football [7], baseball [8], ice hockey [9] and tennis [10] have shown improvements to speed and accuracy of decision making through perceptual training. Recent research [11] also suggests playing video games is a viable

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conduit for the prerequisite knowledge required for sport expertise.As aforementioned, video games are engaging and have the capacity to detect various levels of expertise [4] and influence learning [3].

As stated before, decision making in sport is significantly affected by knowledge. Video games help a person learn appropriate cues (major points in technique) for various situations that can be related to possible real-world situations. Therefore, a person is more inclined to use properresponses during a real-life situation resembling the situations learned from the video game [11]. Another advantage of a video game is that it offers clear objectives for the learner. This is important because these objectives/goals can be adapted to skills and knowledge of the player [3]. The games can also be adapted to each individual player's learning ability and pace of learning, which helps ensure that they learn the goals of the game. Video training provides realistic situations, and allows the individual player to react within its context. In a video game, the player may not respond appropriately or make the correct decision, butthey receive immediate feedback. This feedback enables them to rethink their decision and ultimately lead to the correct response in a similar situation. The repetition and feedback of video games allow a player to learn correct decisions (accuracy) in the context of the game and use the learned information for future reference. Along with learned accuracy, the repetition of the situational decision making leads to making faster decisions.

A relatively new technique becoming more evident in the field of teaching and coaching is the use of virtual reality (VR) as a model of instruction. VR is an increasingly common term to refer to the real-time computer-generated simulation of a three-dimensional environment that replaces the natural sources of stimulation of the real world by artificialstimulation in different channels [12]. VR has been successfully applied to a broad range of training domains and evidence supports the use of VR as a promising tool for the rehabilitation process of patients with neuromotor dysfunction [13]. However, to date there is little research investigating the use of VR for sport training. No studies could be located in which the use of virtual reality training was used to examine its influence on real-world sport skill.

Shooting is one of the defining actions in hockey and searching for performance indicators that help to achieve success in this skill is one of the most commonly raised issues of applied biomechanics in hockey. Puck velocity and accuracy are considered the main factors that contribute to a successful shooting outcome. In the past, it has been shown that short-term training (6 weeks) may be sufficient to achieve significant improvements in sport knowledge and accuracy of decisions[11]. Studies that have focused on clarifying the evolution of shooting performance with advancement in chronological age are still discordant.

It has been said that ice hockey is the fastest game in the world played on two feet. Since 1984, there has been an increased emphasis on training methodology among professional hockey teams [14]. However, most programs have evolved by trial and error, with training methods borrowed from other sports. Training specificity is imperative for successful performance of the elite athlete. Ice hockey training programs should be designed on the bases of relevant objective evaluations. As much as possible, training should be task-specific to match the sports demands. Previous hockey training experiments have primarily focused on training designed to enhance VO_{2max}among participants. However, little information exists related to training programs, the timeline required to develop key skills. Science and hockey await the answers to these questions.

Previous literature on this topic points to the existence of a gap between research on sports biomechanics and the teaching-learning-training process. In this sense, velocity and accuracy have not been examined simultaneously in the studies published to date. The prioritization or selection of only one parameter (e.g., velocity) may represent a significant loss of the otherparameter (e.g., accuracy), as shown in previous literature suggesting a speed-accuracy trade-off in other sports such as soccer.A great need still exists to apply exercise science to the game of ice hockey [14].Although much has been written about the physiology of ice hockey, there is little information about training specificity. Fundamental questions remain as to actual psychomotor responses to training and there is a demand to find answers pertaining to appropriate training methods for today’s ice hockey players.

2. Objective

The purpose of this study was to address the question of whether virtual reality (VR)training can improve real world hockey shooting performance. If so, is the increase in skill relative to initial hockey experience? What effect does VR practice have on velocity and accuracy of on-goal shooting?

3. Methodology

3.1 Participants

Twenty four volunteers were recruited through flyers and word-of-mouth and randomly selected (coin flip) to complete the virtual training intervention or enter a control group with no training. Participants in the control group were asked to continue usual daily activities and not to begin new initiatives in hockey or video gaming during the study. The project was approved by the Institutional Review Board, Human Subjects Review Committee.Informed consent (and assent for minors) was obtained from all participants.

3.2 Procedures

Four primary types of data were collected: (1) participant’s experience with video games and hockey, (2) participant’s motivation toward video game use, (3) participant’s technical performance on three real-world hockey, and (4) participant’s technical performance in virtual hockey. Data were collected prior to the first training session (baseline) and following the completion of the training program (end line).

3.3 Appointment #1 (Treatment and Control Groups)

3.3.1 Hockey Experience Questionnaire

Participants described their hockey participation experience by reporting their highest level of competitive participation ranging from *never played hockey* to *participated in professional hockey*. Information was also obtained for video game and hockey exposure.

3.3.2 Sport Video Game Motivation Scale (SVGMS)

The scale [15] includes seven factors (Competition, Diversion, Enjoyment, Fantasy, Interest with Sport, Social Interaction, and Sport Knowledge Application) with a total of 25 items that are used to identify participant attitudes and behaviors associated with sport video gaming.

3.3.3 Real-World Skill Performance

All participants performed 25 forehand and 25 backhand real-world hockey shots on an empty goal. The average velocity (mph) and accuracy (%) of all trials was used for the quantitative analysis.

3.3.4 Virtual Reality Sessions

Using a HTC Vive Virtual Reality System, participants were given a 15-minute practice period to familiarize themselves with player movement options for a video hockey game called VR Hockey League. After a 15-minute practice session, participants were asked to play the game for about 15 minutes and a researcher recorded the results of the game at the end.The virtual reality sessions were standard and constant for each participant in each session meaning that each participant was exposed to the same set of observations and practices opportunities during the practice session.All participants will be observed target shooting on goal. As with the real-world trials, the average velocity (mph) and accuracy (%) of all virtual trials was recorded.At the end of each practice session, each participant was asked to refrain from reading about, studying, playing, or watching hockey until finished with the study.

3.4 Appointments 2-4 (Intervention Group Only)

3.4.1 Virtual Reality Session

Using a HTC Vive Virtual Reality System, participants were asked to play the same virtual reality game assigned at Appointment #1 for 60 minutes and a researcher recorded the results of the game at the end.These sessions were used to help understand how hockey shooting performance was changing throughout the intervention (if at all). Participants were asked not play video games between appointments.

3.5 Final Appointment (Treatment and Control Groups)

3.5.1 Virtual Reality Sessions

Participants will be asked to play the virtual reality hockey game (same as Appointment #1) for about 15 minutes and a researcher recorded the results (accuracy and velocity) of the game at the end.

3.5.2 Sport Video Game Motivation Scale (SVGMS)

As an endline measure, participants completed the same scale that they were asked to complete at baseline, which included a total of 25 items used to identify participant attitudes and behaviors associated with sport video gaming (and whether or not they changed from baseline to endline).

3.5.3 Real-World Skill Assessment

In the same manner as Appointment #1,all participants were videotaped while performing 25 forehand and 25 backhand real-world hockey shots on an empty goal. The average percent accuracy and velocity of all trials was used for the analysis.

3.6 Control Condition

The control condition was asked to continue with their regular daily lives after the first appointment (baseline) but avoid video game play and participating in hockey for the next six weeks. The control group returned eight weeks after the initial appointment to be assessed a second time on virtual and real-world skill and motivation at endline (last visit).

3.7 Analysis

Descriptive statistics captured critical participant characteristics. The study design was a simple pre-post design with an intervention of four video game play sessions.In order to assess the benefits of practice, a repeated measures MANOVA was completed with practice sessions (stats) as the repeated measure, with skill test scores within the time as dependent variables. Pearson product-moment correlation analyses were conducted to identify the participant correlates related to the virtual performance outcomes.

4. Results

All 24 participants (mean age = 19.88; SD= 10.91) that began the study, completed all sessions. There was an unequal number of males (n = 16) and females (n = 8).Table 1 shows descriptive data for the intervention and control group. Outcome measures were deemed normally distributed after examining skewness, kurtosis, and Q-Q plots within each group.

To examine the effect of virtual training on real-world accuracy, one-way multivariate analysis of variance (ANOVA) indicated that the intervention group demonstrated significantly more real-world hockey accuracy ($F(1,24)$ =15.43, $p< 0.01$, E.S. = 0.56) while shooting on goal than their control group counterparts (intervention M accuracy = 54.17%, SD=12.38, control M accuracy = 46.76%, SD=13.45) at endline.To examine the influence of virtual training on real-world velocity, one-way multivariate analysis of variance (ANOVA) also indicated that the intervention group demonstrated significantly more real-world hockey velocity ($F(1,24)$= 8.50, $p< 0.01$, E.S. = 0.74) while shooting on goal than their control group counterparts (intervention M velocity= 65.50 mph,

Table 1 Descriptive data for theintervention and control group demograghic information.

Group	Factor	M	SD	95% Confidence interval	
				Lower boundary	Upper boundary
Intervention (*n* = 12)	Age	19.00	11.18	12.00	39.00
	Height (meters)	1.57	0.08	1.48	1.68
	Hockey experience	0.67	1.56	0.00	4.00
	VR experience	0.17	0.39	0.00	1.00
Control (*n* = 12)	Age	20.75	10.64	11.00	42.00
	Height (meters)	1.63	0.13	1.58	1.86
	Hockey experience	0.75	1.55	1.00	3.00
	VR experience	0.19	0.49	0.00	2.00

Table 2 Summary of endline skill and motivation ANOVA test results for intervertion and control participants on hockey performation.

Test	Control (*n* = 12)		Intervention (*n* = 12)			
	M	SD	M	SD	F	ES
Hockey accuracy	46.76	13.45	54.17	12.38	15.43**	0.56
Hockey velocity	57.30	13.89	65.50	10.17	8.50**	0.74
VR accuracy	46.67	11.69	51.17	12.40	4.86*	0.33
VR velocity	55.81	9.99	61.53	18.45	5.98*	0.41
Motivation	77.67	37.44	82.33	32.61	3.54*	0.14

Accuracyscore is a percentage; velocityscore is miles per hour (mph).

*$p< 0.05$;

**$p< 0.01$.

SD=10.17, control M velocity= 57.30 mph SD=13.89) (Table 2).

To determine if participant motivation changed from pre to post, ANOVA repeated measures with group (treatment or control) and time as independent measures and Sport Video Game Motivation Scale [15] scores as the dependent variable were completed. The univariate tests produced significant results for within subjects of intervention participants (F(1,24) = 3.54, $p< 0.05$, E.S. = 0.14), who improved their motivation over the course of the study (baseline M motivation = 75.45, SD = 35.31, endlineM motivation = 82.33, SD = 32.61).

As predicted,one-way multivariate analysis of variance (ANOVA) indicated that the intervention group demonstrated significantly more virtual hockey accuracy at endline (F(1,24) = 4.86, $p< 0.05$, E.S. = 0.33)while shooting on goal than their control group counterparts (intervention M accuracy = 51.17%, SD=12.40, control M accuracy = 46.67%, SD=11.69). Additionally, the intervention group demonstrated significantly more virtual hockey velocity at endline (F(1,24)= 5.98, $p < 0.01$, E.S. = 0.41) while shooting on goal than their control group counterparts (intervention M velocity = 61.53%, SD=18.45, control M velocity = 55.81%, SD=9.99).

Pearson product-moment correlation regression equation analyses were conducted to identify the participant characteristic and correlates contributing to real-world and virtual hockey shooting performance (Table 3). The correlation analysis revealed a number of statistically significant relationships. The strongest relationship identified was that virtual hockey shooting velocity (pre) was significantly related to real-world hockey shooting accuracy (pre) ($r = 0.67$, $p = 0.01$). Hockey experience was significantly related to real-world hockey shooting velocity (pre) ($r = 0.82$, $p = 0.05$), real-world hockey shooting velocity (post) ($r = -0.45$, $p = 0.05$), and virtual hockey shooting velocity (post) ($r = -0.43$, $p = 0.05$).

Table 3 Correlations among real world and virtual reality hockey performance outcomes.

Variable	1	2	3	4	5	6	7	8	9	10
1. WVGP	---									
2. HCL	-0.10									
3. Hockey accuracy (pre)	0.07	0.48*								
4. Hockey accuracy(post)	0.03	0.50*	0.67**							
5. Hockey velocity (pre)	0.82*	0.18	-0.18	-0.25						
6. Hockey velocity (post)	-0.45*	-0.13	-0.35	-0.23	0.58**					
7. VR accuracy (pre)	-0.01	-0.27	-0.28	-0.38	0.29	0.44*				
8. VR accuracy (post)	0.14	-0.27	-0.34	0.16	-0.04	0.43*	0.30			
9. VR velocity(pre)	-0.24	-0.10	0.61**	0.45*	-0.23	-0.20	-0.38	-0.21		
10. VR velocity (post)	-0.43*	-0.14	0.41*	0.18	0.18	0.17	-0.14	-0.07	0.72**	---

HCL = heights competitive level; WVGP = weekly video game playing (hours).
** Correlation is significant at the 0.01 level (2-tailed);
* Correlation is significant at the 0.05 level (2-tailed).

Table 4 Descriptive data for the MANOVA repeated measures with intervention group and time (three practice sessions) for dependent variables of velocity and accuracy of hockey shooting on goal.

Main effects	Time	M	SD	Effect size
Real world scores				
Accuracy (%)	Pre	35.42	13.00	1.52**
	Post	54.17	12.40	
Velocity (mph)	Pre	54.19	15.74	0.86*
	Post	65.50	10.17	
Virtual reality scores				
Accuracy (%)	Pre	26.67	8.35	3.89**
	Post	52.92	5.31	
Velocity (mph)	Pre	53.68	10.64	0.54
	Post	61.53	18.45	

*$p< 0.05$;
**$p< 0.01$.

One-way multivariate analysis of variance (MANOVA) repeated measures using the three practice sessions (intervention) as the fixed factor indicated significantly higher outcome scores on real-world accuracy (35.42% versus 54.17%; E.S. = 1.52)and velocity (51.10 mph versus 65.50 mph; E.S.=0.86) of hockey shooting on goal from pre to post, all demonstrating a meaningful training effect (Table 4). To examine virtual skill differences from pre to post, one-way multivariate analysis of variance (MANOVA) also reported higher and meaningful outcome scores at endline compared to baselin33e for virtual accuracy (26.67% versus 52.92%; E.S. = 3.89) and velocity (53.68 mph versus 61.53 mph; E.S. = 0.54), demonstrating that virtual performance also improved from pre to post.

5. Discussion and Conclusion

The purpose of this study was to address the question of whether virtual reality (VR) training can improve real world hockey shooting performance. This is the first experimental investigation using treatment and control to examine the effect of virtual training on real-world hockey skill. Hockey experience for participants in this study ranged from having played no organized hockey (*n*=18) to high school hockey (*n*=4). This research supports the idea that virtual training is an effective tool for increasing sport skill. Results indicate real-world hockey performance was positively influenced by virtual training (Table 2). Participants' skill increased with exposure to the virtual training (video game). Compared to control, the intervention group significantlyimproved both accuracy and velocity of real-world hockey shooting on goal. The large effects sizes for accuracy (0.56) and velocity (0.74) showed that the intervention also had a meaningful influence on the outcome of real-world hockey scores. This is noteworthy because the time for the intervention was short (four 30-minute sessions) and the intervention was simple (play a video game). Previous literature has shown that video games were effective teaching tools [3, 11] but little research has examined the effect of virtual reality training in sport.

These results demonstrate meaningful differences in the skill test scores form pre- to post intervention. Contrary to the findings of this study, previous literature suggests active video game play using the Nintendo Wii is unlikely to build skill. This study supports the idea that virtual training using the HTC Vive can be used to increase isolated physical movement skills as a foundation for expertise in sport, and it does so in ways that the Nintendo Wii does not. Participants were focused on learning the central sport-specific skills associated with virtual training, and improved not only hockey shooting accuracy and velocity on goal, but also increased incidental motivation as measured by the Sport Video Game Motivation Sale [15].

Consistent with previous literature [13] real-world skill was related to the virtual skill demonstrated via video game play. What this study adds to the literature is that virtual training in hockey can also be used to improve real-world skills in as little as four training sessions. Coaches should understand the technical aspects of sport skills, the strengths and weaknesses of various strategic approaches to sport, the training implications for improved performance in sport, the developmental considerations related to sport, and technologies within a sport [16]. Participants in this study demonstrated significantly more real-world accuracy and skill as a result of virtual training. In addition, participants also improved their motivation towards sport video games from pre to post. This suggests that virtual sport training could help individuals improve both physical skill and psychological attitudes towards the sport—an important finding but not surprising considering youth prefer to engage in technology-related activities over physical activity [17].

Consistentwith the theory and research in sport expertise, the participants in this study increased skill as a result of virtual training and those with more experience at the start of the study performed better than less experienced participants. All participants improved their accuracy and velocity, but those performers that improved accuracy the most demonstrated the smallest improvements in velocity from pre- to post, suggesting a speed-accuracy trade-off exists in virtual sport performance. In a manner similar to real-world sport, as the need for accuracy increased there was a decrease in speed (velocity).

There exists a lack of research examining the empirical effects of technology on physical outcomes [18]. This work sheds light on the field of virtual training in sport and suggests that virtual training could help coaches develop accuracy and velocity in sport skills (beyond a rudimentary level).The HTC Vive represents one way to evaluate mastery of hockey skills and it may benefit teachers or coaches with the least amount of knowledge or skill. A study design and analysis taking into consideration other offensive and defensive skills on ice could provide a better representation regarding overall hockey skill.

5.1 Limitations

The recruitment for this study was not random due to the need for novice participants of a certain age. Each participant was asked not to participate in hockey video games or virtual reality during the intervention, but there was no way to have complete control over these variables. The intervention involved only hockey shooting skills with measures for accuracy and velocity, so the virtual training was biased to offense and the demonstration of skills in isolation without an opposing defense. A study design and analysis taking into consideration other offensive and defensive skills on ice could provide a better representation regarding overall hockey skill.

5.2 Future Recommendations

Video games have been shown to be useful tools in increasing both knowledge and skill, but rarely have they been used in the realm of sport. Previous studies have shown video games to increase knowledge and create effective training methods in areas unrelated to sport [6] and even their use in sport to increase skill improvement[19] and speed and accuracy of decision making in sport [11]. This study shows different patterns in virtual training on sport-specific skills, but does not involve contextual situations to examine the influence of VR training on knowledge or decision making. Virtual sport experience leveraging the latest technology appears to offer tremendous learning opportunity. While the current study suggests virtual training can improve the accuracy and velocity of real-world hockey shooting on goal in isolated practice settings, it remains unknown whether such skills would be effectively applied during actual game play. Future research can help construct an efficient method of increasing sport knowledge, decision-making, and gameplay in sport. There are unanswered questions about the use of virtual training to enhance game play and coaching potential. Future research should also examine additional opportunities for learning beyond the changes identified in the current study and whether or not there is a plateau effect to this improvement.

References

[1] Deakin, J.M., and Cobley, S. 2003. "An Examination of the Practice Environments in Figure Skating and Volleyball: A Search for Deliberate Practice." In *Expert Performance in Sports; Advances in Research on Sport Expertise*, edited by Starkes, J., and Ericsson, K.A. Champagne, IL: Human Kinetics.

[2] Horton, S., and Baker, J. 2004. "A Review of Primary and Secondary Influences on Sport Expertise."*High Ability Studies* 12: 211-28.

[3] Swing, E.L., and Anderson, C.A. 2008. "How and What Do Video Games Teach?" In *Children's Learning in a Digital World*. Oxford, UK: Blackwell.

[4] Buns, M., and Thomas, K.T. 2011 "Convergent Validity between a Sport Video Game and Real Sport Performance." *Sports Technology* 4: 77-87.

[5] Corbett, A.T., Koedinger, K.R., and Hadley, W. 2001. "Cognitive Tutors: From the Research Classroom to All Classrooms."In*Technology Enhanced Learning*,edited by Goodman, P.S.Mahwah, NJ: Lawrence Erlbarum.

[6] Prensky, M. 2001. *Digital Game-Based Learning.* New York, NY: McGraw-Hill.

[7] Londere, B.R. 1967. "Effect of Training with Motion Pictures versus Flash Cards upon Football Play Recognition." *Research Quarterly for Exercise and Sport* 38: 202-7.

[8] Burroughs, W.A. 1984. "Visual Simulation Training of Baseball Batters."*International Journal of Sport Psychology* 15: 117-26.

[9] Thiffault, C. 1974. "Tachistoscopic and its Effect upon Virtual Perceptual Speed of Ice Hockey Players." In *Proceedings of the Canadian Association of Sport Sciences.*Edmonton, Alberta.

[10] Haskins, M.J. 1965. "Development of a Response-Recognition Training-Film in Tennis."*Perceptual Motor Skills* 21: 207-11.

[11] Sanger, M., Buns, M., and Thomas, K.T. 2019 "The Effect of Virtual Training on Speed and Accuracy of Decision Making in Sport." *Journal of Human Kinetics* 70: 235-43.

[12] Borrego, A., Latorre, J., Llorens, R., Alcaeiz, M., and Non, E. 2016. "Feasibility of a Walking Virtual Reality System for Rehabilitation: Objective and Subjective Parameters." *Journal of NeuroEngineering and Rehabilitation*13: 1.

[13] Pavao, S.L., Arnoni, J.L., De Oliveira, A.K., and Rocha, N.A. 2014. "Impact of a Virtual Reality-Based Intervention on Motor Performance and Balance of a Child with Cerebral Palsy: A Case Study." *Pediatria*32: 389-94.

[14] Cox, M.H., Miles, D.S., Verde, T.J., and Rhodes, E.C. 1995. "Applied Physiology of Ice Hockey."*Sports Medicine* 19: 184-201.

[15] Kim, Y., and Ross, S. 2006. "An Exploration of Motives in Sport Video Gaming."*Journal of Sports Marketing and Sponsorship* 8: 28-40.

[16] Siedentop, D. 2002. "Content Knowledge for Physical Education."*Journal of Teaching in Physical Education* 21: 368-77.

[17] Allison, K., Dwyer, J., Allan, F., Yoshida, K., and Bouliter, M. 2005. "Male Adolescents' Reasons for Participating in Physical Activity, Barriers to Participation, and Suggestions for Increasing Participation."*Adolescence*40: 155-6.

[18] Russell, W., and Newton, M. 2008. "Short-Term Psychological Effects of Interactive Video Game Technology Exercise Mood and Attention."*Educational Technology and Society* 11: 294-308.

[19] Barnett, L., Ridgers, N., Reyonolds, J., Hanna, L., and Salmon, J. 2015. "Playing Active Video Games May Not Develop Movement Skills: An Intervention Trial." *Preventive Medicine Reports* 2: 673-8.