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Do player performance, real sport experience, and gender affect movement patterns during equivalent exergame?

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A B S T R A C T

This study compared the movement patterns of forty-six college students, playing bouts of swimming exergame, while categorized based on their playing performance, gender, and prior experience of real swimming and exergames. Swimming events were divided into normal (controlled by visual feedback) and fast (no feedback) phases and upper limb kinematics were monitored during front crawl event. Those who performed better, completed the game with fewer upper limb cycles and in a shorter time ($p < 0.003$). Prior exergame experience resulted in higher start velocity ($p = 0.019$) and those who were familiarized with this swimming exergame, completed the front crawl event with fewer cycles ($p = 0.022$). Gender and real swimming experience did not affect biomechanical variables. With various playing styles and differences to real swimming movements, the data suggest that the motion capture device is not able to detect complex movements of swimming and previous knowledge of real swimming do not necessarily transfer into better exergame performance. These changes might have happened due to higher adaptation to the exergame. Understanding these patterns may help in the development of more realistic sport exergames and meaningful gameplay.

1. Introduction

Despite documented benefits of physical activity, many people are still living inactive lifestyles. Interventions for decreasing sedentariness for overweight youth typically fail, because of low motivation and high attrition rates (Sardinha et al., 2012; Summerbell et al., 2005). Youth may also stop regular physical activity during their adolescence, which may lead to weight gain (Slater & Tiggemann, 2010). Moreover, there are some other well-identified contributors to physical inactivity, namely the lack of access to physical education at school (Brownson et al., 2000), being a racial/ethnic minority group (Brodersen, Steptoe, Boniface, & Wardle, 2007), having low socioeconomic status (Kristjansdottir & Vilhjálmsson, 2001), and engaging in prolonged television watching (Hu, Li, Colditz, Willett, & Manson, 2003). As part of screen-based activities, video game playing is increasing among youth, and has changed significantly from arcade games to accessible video games (Lenhart et al., 2008). However, high exposure to video games has raised psychological and physiological concerns (Roberts, Foehr, Rideout, & Brodie, 2003), leading to the design of exergames in which players have to interact using their body (requiring some degree of physical activity). Using Kinect, a low-cost motion capture sensor, players do not have to hold any extra gadgets during the gameplay and the sensor can detect full body joint segments (Zhang, 2012), providing indoor experiencing of many sport-related activities.

According to specificity of training principle, repeating similar movements may provide skilled behavior (Barnett, Ross, Schmidt, & Todd, 1973) and, as sport exergames consist of many repetitive movements, they might potentially be helpful or detrimental in

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improving fundamental movement skills (FMS) which are the basis of more complex and specific sport motor skills (Lubans, Morgan, Cliff, Barnett, & Okely, 2010). It has been also proposed that for an optimal performance between specific activity (real sport) and a repeated task (sport exergame), task constraints should be similar (Newell, 1989). For example, Downs, (2008), found that putting a golf ball in a Nintendo Wii game, actually led to net gains in the refinement and production of real putting behavior. Such naturally mapped exergame controllers provide an interactive, dynamic, and enjoyable experience and might increase feelings of self-efficacy and learning exercise behavior (McGloin, Farrar, & Krcmar, 2011; Skalski, Tamborini, Shelton, Buncher, & Lindmark, 2011). On the other hand, excessive exergame playing may also lead to injuries, indeed, conditions such as Wii-shoulder (Cowley & Minnaar, 2008), Wiiitis (Bonis, 2007; Nett, Collins, & Sperling, 2008), and X-boxitis have been previously recognized by medical doctors. Specific injuries and risks associated with excessive practice are important, especially when players are not completely aware of their bodies and surroundings. Therefore, evaluation of movement patterns is essential for designing exergames and realistic sport games should require movements determining good performance.

Previous research suggests that although exergames require active participation, they are usually less demanding than real-world exercises (Graves, Ridgers, & Stratton, 2008). Movements during exergaming are highly different (Levac et al., 2010) and depending on games, consoles, and strategies that different players employ, patterns vary from full body to small wrist movements. For example, it was shown that kinematics of real and virtual tennis differ (Bufton, Campbell, Howie, & Straker, 2014), and experienced real-football players had smaller reaction time and made fewer corrective movements compared to novice players during a virtual football video game (Savelsbergh, Williams, Van Der Kamp, & Ward, 2002). Previous research also showed that quantity of movements in experienced exergame players is not different than the ones of novice players (Levac et al., 2010). Moreover, physiological evaluations show that males and females are equally active during exergaming sessions (Sun, 2013), but there are contradictory results regarding time spent playing exergames between the two genders (Sit, Lam, McKenzie, Sit, & Lam, 2010). While there are non-modifiable challenges during playing sport exergames (e.g. lack of forces from water in swimming exergame or holding a physical racket during tennis), for a more meaningful experience, movement patterns should be as close as possible to real sports. More detailed evaluations are needed to provide evidence for the benefits of sport exergames and, if showing movement behavior similar to real sports, they can potentially be a low-cost tool in increasing physical activity and skill acquisition. As research investigating the amount of movement and different strategies of playing in exergames is scarce, we have purposed to compare upper limb kinematics in a swimming exergame between players with different game performance, prior real swimming and exergame experience, and gender.

2. Methods

2.1. Participants

35 male and 11 female college students (mean ± SD 24.4 ± 4.4 vs. 27.3 ± 7.2 years of age, 1.77 ± 0.07 vs. 1.66 ± 0.06 m of height, and 72.7 ± 10.8 vs. 58.4 ± 7.1 kg of body mass, respectively) were recruited through word of mouth, flyers, and online advertisement. The procedures were approved by local ethics committee (Process number: CEFADE 01/2013) and, prior to testing, participants signed the informed consent. Data from participants' preferred upper limbs were considered in the analysis.

2.2. Procedures

Twenty-two spherical reflective markers of 20 mm were placed on the anatomical landmarks over the skin (cf. Rab, Petuskey, & Bagley, 2002): 7th cervical vertebrae, acromio-clavicular joints, lateral and medial epicondyles approximating elbow joints, wrist bar thumb side and pinkie side (radial styloid and ulnar styloid), dorsum of the hand just below the head of the second and fifth metacarpal, inferior lower border of scapula bones, sacrum, sternum, anterior-superior, and posterior-superior aspects of iliac crest. The 3D position of each marker was simultaneously recorded at 200 Hz using a 12 camera motion capture system (Qualisys AB, Gothenburg, Sweden) using a specific acquisition software (Qualisys Track Manager, Qualisys AB, Gothenburg, Sweden).

Subjects played different techniques (100 m each) in a swimming exergame designed for Microsoft Xbox and Kinect (Michael Phelps: Push the Limit, 505 Games, Milan, Italy). The gameplay was divided into two phases (normal and fast) and the upper limb kinematics during front crawl was monitored. Players' performances were ranked from 1st to 8th and categorized as "Good" (1st to 4th) and "Bad" (5th to 8th) in a swimming exergame competition. Players ranked their real swimming and exergame experience from 1 to 5 where 1 was novice and 5 was experienced (including front crawl). If subjects played backstroke, breaststroke, or butterfly techniques before front crawl, we considered them as experienced with the exergame (swimming exergame experience).

During the front crawl event, subjects had to stand in front of the Kinect sensor and bend forward (preparatory position; Fig. 1, panel A) and, as soon as they saw the visual command, they had to return back to standing position with upper limbs in front (Fig. 1, panel B). Afterward, subjects had to swing their upper limbs (Fig. 1, panels C, D, and E) to move the avatar in the game. At the middle of the second lap, there was a possibility to swim as fast as possible called "Push the Limit". At the end of the event, they had to drop their upper limbs (Fig. 1, panel F) and then raise one to finish the race (Fig. 1, panel G). To prevent from too fast or too slow gameplay, an on-screen visual feedback bar indicated if the speed was at the moderate level.

2.3. Data collection and analysis

Before each experiment, cameras were calibrated to the measurement volume of 5 m deep by 3 m wide by 3 m high, in front of the Kinect sensor. A 10 s static trial was recorded for each subject while standing in an anatomic position, as the baseline measurements for processing the kinematic data. Subjects were asked to wear bright clothes that neither absorb nor reflect the light that causes gaps in 3D detection/reconstruction (Dutta, 2012). Three consecutive front crawl upper limbs cycles in each phase were considered in the analysis and a 3D motion analysis package (Visual3D, C-Motion, Rockville, MD) was used to compute joint kinematics. The laboratory and segment local coordinate systems were defined as illustrated in Fig. 2, with the local coordinate system defined at the proximal joint center for each segment. For the elbow and hand, the joint centers were located mid-way between the humeral medial and lateral epicondyles and the midway between the markers placed on the second and fifth metacarpals, respectively.

Table 1 lists kinematic variables that were measured during the exergame play and demographic and kinematical data were presented as mean ± SD and subjects within each performing groups were compared using one-way analysis of variance (ANOVA). Normality and homogeneity of variance were checked and, in the case of abnormal distribution and non-homogeneity, alternative statistics were applied. Outcomes of kinematic variables across