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Original Article

Energy expenditure and total volume of physical activity while playing active videogames

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Abstract
Objective – To compare physical activity, via accelerometers secured in three different attachement site, and determine the correlation between estimates of METs by accelerometry and indirect calorimetry in adults playing different active videogames. **Methods** – Participants (n =54) played four active videogames that simulate sports activities using an Xbox 360 Kinect™ (10 minutes/each): athletics, bowling, boxing and bach volleyball. The accelerometers (ActiGraph® GT3XE-Plus) were positioned in three different location (wrist, hip, and ankle) to determine the counts and predicted METs values. The Cosmed K4b2 portable metabolic analyzer (indirect calorimetry) measured the Actual METs. Analysis of variance (multi-factor model), Student's t-test for paired samples, and Pearson's correlation were used to test the data (level of significance of 5%). **Results** – The correlation between counts and Actual METs depended on the game type and accelerometer positioning. Athletics and beach volleyball video games presented positive correlations between the Actual METs and counts in all axis (vertical, horizontal, perpendicular, and vector's magnitude). There was an interaction between the accelerometer location and the different games ($F=575.324$, $p<0.001$). The hip accelerometer presented the biggest mean counts values in all the sports games. There wasn´t a significant difference between the games according to the hip accelerometer. In all games, the Actual METs values were superior ($p<0.05$) to those estimated by the accelerometer (hip). There was a positive correlation only for beach volleyball game. **Conclusion** – The counts versus Actual METs relationship for accelerometry are exclusive to the attachement site and the games. The accelerometry underestimate the values of METs.
Keywords - Video Games, Energy Metabolism, Accelerometry, Adults

Introduction

The regular practice of physical activity has been shown to have positive effects in metabolic, cardiovascular, and functional parameters. However, the number of people involved in sedentary activities for lengthy periods of time is still long (Verloigne et al., 2016), which has led to interest in preventive and health surveillance strategies that promote better health and life quality (Althoff et al., 2017).

Active videogames (AVG) that combine the playing of a videogame with body movements are one alternative to increase the level of physical activity and energy expenditure (GE) among people of varied ages (Clevenger & Howe, 2016; Graves et al, 2010; Taylor et al., 2012). AVG products have been mostly targeted home markets and among the available technology, the Xbox Kinect[tm] stands out from its competitors (i.e., PlayStation®, Nintendo® Wii) because it does not require hand controls. The Kinect[tm] system allows the interaction and control of the games to be made by body movements alone. Therefore, the player engages the whole body while playing, increasing energy expenditure in the process (Clevenger & Howe, 2016).

Monitoring of the physical activity and prediction of energy expenditure while playing an AVG are crucial to identify genuine health benefits. Indirect calorimetry is a traditional way to evaluate energy expenditure, but it is relatively expensive, requires training, and may be uncomfortable for the player while playing (Kim, Angermann, Bebis & Fomer, 2013).

Alternatively, some authors used accelerometry to quantify human movement while participants were using AVG (Taylor et al., 2012; Tripette et al., 2014). Accelerometers are reliable, objective, and less expensive compared to other ways of estimating energy expenditure during physical activity (Ndahimana & Kim, 2017). The output of accelerometry has been presented in counts, which are proportional to the variation of acceleration of movements (Chen, Janz, Zhu & Brychta, 2012), and in predicted metabolic equivalents of task (METs) (Cuberek, Fromel, Groffik, & Jakubec, 2017; Lyden, Kozey, Staudenmeyer, & Freedson, 2011). In general, waist-worn attachment site has been used for monitor physical activity and time spent in sedentary behavior (Loprinzi & Smith, 2017; Kozey, Lyden, Howe, Staudenmayer, & Freedson, 2010). However, there has been interest in using the accelerometer in other anatomic location as wrist and ankle in different physical activities (Loprinzi & Smith, 2017; Ozemek, Kirschner, Wilkerson, Byun & Kaminsky, 2014; Rosenberger et al., 2013).

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Independent of the system (Nintendo Wii, PlayStation, or Xbox Kinect), AVGs' themes are related to dancing, fitness, and sports, with different movement specificities (Lyons, Tate, Bowling, Ribisl, & Kayararaman, 2011). Since the energy expenditure depends on the demands put on the body as it engages in a particular game (Graves, Ridgers & Straton, 2008), the attachment site of the accelerometer may interfere in the counts and predicted METs values. In addition, due to the specificity of the movements, the anatomic placement of the accelerometers might underestimate or overestimate the energy expenditure of each physical activity (Loprinzi & Smith, 2017; Tudor-Locke, Barreira & Schuna, 2015).

We hope in this study to contribute to the knowledge and discussion of the best location on the body to set the accelerometer in order to calculate the energy expenditure and volume of physical activity while an individual is playing an AVG. The objectives of this study were 1) to compare the physical activity in adult players, as evaluated by an accelerometer positioned on three anatomic locations; and 2) to determine in kinect-assisted AVGs the correlation between the estimates of the metabolic equivalent by accelerometry and by indirect calorimetry.

Material & Methods

This analytical-descriptive study followed a protocol approved by the Ethics Committee on Human Research of the Universidade Federal de Santa Catarina.

Study participants were 54 individuals (convenience sampling) of both sex. All volunteered to be part of this research. Individuals were 21 years of age or older, all members of the academic community of universitiy (i.e., graduate and post-graduate students, professors, staff, and participants in community extension program). The criteria for exclusion from the sample were: use of medicine for depression; a diagnosis of hypertension, cardiovascular disease, thyroid hormonal disorders, orthopedic injury or moving difficulty; or an impairment of vision or hearing that could interfere in perceptions of color, images or sound identification. Regular AVG players were also excluded from this study. The gathering of data was accomplished in one session by trained interviewers familiar with the standardizations of evaluations and techniques applied. The video games were played on a Microsoft Xbox 360 com Kinect. The projection screen area of the Kinect sensor was 4.2 meters. Participants played the video games by themselves.

We used the following games that simulate sports from the Kinect Sports Ultimate Collection (1st and 2nd Seasons): boxing, bowling, beach volleyball, and athletics (100-Meter Race, Long Jump, Javelin Throw and Hurdles Race). The choice of the games was made based on the preferences of the participants in the pilot study. Each sport was played for 10 minutes with a five-minute break between each one. The sports games presented three levels of difficulty: beginner, intermediate, and professional. All players started as beginners, progressing to the next levels as they won a game. If they didn´t win, they would remain on the same level until the 10-minute period was up. The total volume of physical activity (counts) was measured by accelerometers (brands/models: ActiGraph®, ActiGraph LLC, Pensacola, Fla, USA; model GT3XE-Plus - Triaxial Activity Monitor) across three axes and vector magnitude (the square root of the sum of the squares of the vertical, anterior-posterior and medial-lateral axes) (Ozemek et al, 2014). Each device was placed, simultaneously, in three anatomic locations: wrist (ulnar styloid process), hip (anterior axillary line at the level of the iliac crest) and ankle (above the lateral malleolus). The devices were placed on the dominant side preferred by the player.

The accelerometer's data were discharged in 10 seconds-epocs (software Actilife 6.11.5, ActiGraph, Pensacola, FL). The number of "counts" (the units of measurement of the accelerometers) of each game was analyzed for each device (on the wrist, hip, and ankle). The estimate of the metabolic equivalent (METs) was assessed by accelerometer (predicted METs) and indirect calorimetry (Actual METs). The predicted METs (continuous variable) was determined during each game only for the hip area by Freedson Equation (Freedson, Melanson & Sirard, 1998). A portable system for pulmonary gas exchange (COSMED K4b2) was used to collect expired respiratory gases on a breath-by-breath basis to measure METs (VO2 of the activity (ml(Kg.min)$^{-1}$) / VO2 at rest (ml(Kg.min)$^{-1}$). The device is portable and employ a rubber face mask and a turbine for gas collection, secured by a headpiece adjustable to ensure a proper fit. It was calibrated with standard gases prior to each measurement session, according to the manufacturer's recommendations. METs were averaged using data collected during the last 5 minutes of each ten-minutes/each game (Pinnington, Wong, Tay, Green & Dawson, 2001). Descriptive variables: sex, school level (i.e., elementary school, middle school, high school and post-secondary school), physical activity (yes or no), and previous experience with an AVG (never played/played only once; played many times).

Statistical Procedure

General characteristics were expressed as mean±standard deviation and frequencies. The correlation (r) between the volume of physical activity (counts.min^{-1}) and METs (indirect calorimetry) was determined by Pearson correlation. The mixed models analysis was used to compare the values of counts.min^{-1}, of Vector Magnitude, based on the game and placement of the accelerometer. The multiple comparisons were analyzed by post-hoc Sidak test. The Student t-test for paired samples and the correlation (r) by Pearson's test compared the values of METs (predicted, by accelerometer on the hip, and Actual, by and by indirect calorimetry). In all analyzes, the statistical significance level was set at 5% ($p \leq .05$). Data analysis was performed using the Statistical Package for Social Sciences (SPSS version 22.0).

Results

The study sample consisted of 54 participants (34.2 ± 12.9 years old). Most participants were graduates, single, practiced some regular physical activity, and had never previously played an exergame or had played only once (table1)

Table 1.
Characterization of the participants.

Variáveis	N	%
Sex		
Female	28	51.9
Male	26	48.1
Scholarity		
High school	10	18.5
Higher education	44	81.5
Physical activity		
yes	41	75.9
No	13	24.1
Play exergame		
No, never	27	50.0
Yes, once	8	14.8
Yes, sometimes	17	31.5
Yes, constantly	2	3.7

Table 2 presents the correlation data (r) between counts (accelerometer) and Actual METs, according to each sport game. For athletics, only the values of counts from the accelerometer when placed on the ankle presented a correlation with the value of METs (5.53±1.04), both for the axes X, Y, Z, and for the vector magnitude. For the bowling game, there was a correlation between the METs (5.60±1.43) and the values of counts in the axis Y (horizontal), both for the device placed on the hip (r = 0.351; p = 0.013) and on the ankle (r = 0.301; p = 0.042). There was also a correlation with the vector magnitude for the hip device (r = 0.337; p = 0.017). For boxing, the values of counts presented a correlation with METs (6.40±1.60) only for the axis Z of the accelerometer of the ankle. For the beach volleyball games, there was correlation between METs (5.73±1.09) and the values of counts for the axis Y, as well as for the vector magnitude, both for the accelerometer placed on the hip and on the ankle. For the accelerometer on the ankle, there was also correlation between METs and counts for the axes X, Z and vector magnitude. Table 3 presents comparisons between the mean values (counts) of the vector magnitude by game and by placement of the accelerometer. The mixed models analysis showed an interaction between the locations of the accelerometers and the different games (F=575.324; p<0.001). For all games, the multiple comparisons showed significant differences (p≤0.05) in the mean values of counts when the accelerometers were placed on the wrist, with higher values in bowling and lower in athletics games. As for the accelerometer placed on the ankle, a significant difference was found between the values of counts from athletics and bowling games.

Table 2.
Correlation (r) between counts (epoch/10 seconds) and Actual METs (indirect calorimetry)

		Counts					
	METs	Wrist		Hip		Ankle	
	Mean (SD	Mean (SD)	r	Mean (SD)	r	Mean (SD)	r
Athetics	5.53 (1.04)						
Axis x		7174(4573)	.003	1735 (873)	.115	4993 (1664)	0.452*
Axis y		6849 (3443)	.017	1076 (987)	.144	3216 (1489)	0.382**
Axis z		4319 (2229)	.011	1325 (638)	.114	2077 (1117)	0.326***
Vector's M		10921 (5954)	.014	2496 (1353)	.111	6406 (2179)	0.461*
Bowling	5.60 (1.43)						
Axis x		19527 (9000)	.017	1344 (1185)	.255	826 (1341)	.211
Axis y		16180 (7832)	.100	1754 (931)	.351***	1333 (934)	.301***
Axis z		10552 (5259)	.093	2061 (1194)	.190	924 (693)	.138
Vector's M		27805 (12286)	.063	3241 (1515)	.337***	1949 (1629)	.233
Boxing	6.40 (1.60)						
Axis x		16256 (6434)	.138	1312 (785)	.126	1526 (3575)	.187
Axis y		12038 (4789)	.182	2172 (1046)	-.015	2537 (2466)	.264
Axis z		10057 (4638)	.171	2047 (982)	.249	1914 (1944)	.298***
Vector's M		22716 (8944)	.163	3388 (1344)	.128	3651 (4660)	.237
Volleyball	5.73 (1.09)						
Axis x		9325 (3485)	.150	2427 (917)	.244	1800 (1466)	.392***
Axis y		7564 (2555)	.105	1528 (581)	.339***	2442 (1004)	.425**
Axis z		7664 (2477)	.039	1959 (730)	.223	2079 (1295)	.436**
Vector's M		14320 (4757)	.110	3523 (1165)	.296***	3731 (2106)	.427**

Note. Axis x (vertical); Axis Y (horizontal); Axis Z (perpendicular); Vetor's M (vector magnitude).
* significant at the *p* <. 001 level. **Significant at the *p* < .005 level. *** Significan at the *p* < .05 level.

When each game was compared according to the placement of the accelerometer, it was found that the highest mean values for all games were produced for the wrist location. For athletics, the device placed on the hip presented the lowest values of counts (2496±645). For all other games, there was no difference between the values of counts of when the accelerometers were placed on the hip and ankle (Table 3).

Table 3.
Comparison of counts.min-1 (mean values) of Vector Magnitude per game and location of accelerometer.

	Mean ± SD			
	Athletics (n=49)	**Bowling (n=44)**	**Boxing (n=46)**	**Volleyball (n=47)**
Wrist (n=54)	10921±5955Aa	27805±12286Ba	22716±8944Ca	14320±476Da
Hip (n=50)	2496±645Ab	3241±1515Ab	3388±1351Ab	3523±118Ab
Ankle (n=46)	6406±1878Ac	1949±1629Bb	3650±1404ABb	3731±1024ABb

Note. Mixed model analysis: interaction (modality*device): F=575,324, p<0,001. Post-hoc Sidak.
Minuscule letters compared the devices (wrist, hip and ankle). Majuscule letters compared the games
Equal majuscule letters represents no statistic difference (5%) between the groups. Equal minuscule letters represents no statistic difference (5%) between the times.

Table 4 presents a comparison, according to each game, between the METs assessed by indirect calorimetry (K4) and the METs of the hip accelerometer. There was a significant difference, for all games, between the mean values of Actual METs (indirect calorimetry) and predicted METs. Only for beach volleyball, was there a (low) correlation between the values of METs identified by both methods.

Table 4. Comparison between Actual METs (indirect calorimetry) and predicted METs (hip accelerometer), according to the game.

	Actual METs	Predicted METs	Paired t test	Correlation	
	Mean ± SD	Mean ± SD	p-value	(r)	p-value
Athletics	5.53 ± 1.04	2.50 ± 0.76	<.001	0.135	.341
Bowling	5.60 ± 1.43	2.05 ± 1.22	<.001	0.251	.079
Boxing	6.40 ± 1.60	2.01 ± 0.87	<.001	0.215	.129
Volleyball	5.73 ± 1.09	3.19 ± 0.98	<.001	0.306	.029

Note. SD, standard deviation

Discussion

This study compared physical activity as evaluated by accelerometers placed on three different anatomic attachment site. It also determined the correlation between estimates of the metabolic equivalent by accelerometry and by indirect calorimetry, in Kinect-assisted AVG. The values of counts and METs, as well as the correlation between the measurements, differed depending on the game, the axis analyzed, and the placement of the accelerometer. There was interaction between the placement of the accelerometers and the different games. In all games, the values of METs as assessed by indirect calorimetry were significantly superior to those estimated by the accelerometer placed on the hip.

The results showed that beach volleyball and athletics were the games that presented correlation between the values of Actual METs and counts in all analyzed axes. This happened only for the accelerometer placed on the ankle, probably due to the characteristics of these games. Beach volleyball and athletics present higher movement of the lower limbs, aiming for better performance. The serves and attacks in beach volleyball, races and jumps in athletics demand vertical motion. Moreover, the blocks in beach volleyball and racing in athletics may cause lateral and/or antero-posterior displacement.

It´s important to point out that the axis proposed by the accelerometers evaluate the angular variation of the movement which can be underestimated by lack of practice of the participant and, therefore, limiting joint movements (Clevenger & Howe, 2016). The pattern of motion execution depends on previous experience of the individuals in that sport. Moreover, the pattern of movement and the energy expenditure is higher among more experienced players (Clevenger & Howe, 2016; Sell, Lillie & Taylor, 2008). In this study, we believed that those with previous experience at playing AVGs might not have had experience with the sports played. Thus, as those who had never played, they may have presented irregular patterns of motion, decreasing angular variation while playing the games.

Caution is needed for interpreting results of the correlation between the values of Actual METs and counts, a correlation of data obtained by physiological factors and mechanical factors, respectively. No accelerometry equation is capable of determining energy expenditure as accurately as physiological markers (Corder, Brage & Ekelund, 2007).

In the present study, the placement of the accelerometer proved to be sensitive to the motion's requirements, as identified by other authors in earlier studies with AVG (Taylor et al., 2012) and other physical activities (Loprinzi & Smith, 2017; Ozemek et al., 2014; Rosenberger et al., 2013). In all games, the wrist device identified the highest values of counts, as showed previously (Taylor et al., 2012). The sports games that required the most from superior limbs (i.e., bowling and boxing) had the highest values of counts.

These games characteristics may favor the superior limbs motion more than the total movement. Therefore, the devices placed on the wrist might overestimate the activity, as they will sense any movement from the upper limbs in tasks that require them (Graves, Ridgers & Stratton, 2008). On the other hand, the hip measurement might be considered the one underestimating, and the best would probably come from a mix of both hip and wrist evaluation when possible.

There is no acceptable prediction equation of the METs to the accelerometer´s counts when placed on the ankle and wrist (Ozemek et al., 2014). Therefore, in the presente study, we compared only Actual METs with predicted METs estimated by the hip accelerometer. The results of the comparison showed significant differences with superior values for Actual METs. If AVG play is a new activity for the participants, it may influence the energy demand due to novel demands on muscles and fibers. This could occur even if the participants practice regular physical activity. The placement of the sensor on the hip may not capture data due to little motion of the thorax, underestimating the values of energy expenditure (Hildebrand, Hees, Hansen & Ekelund, 2014). Studies that aimed to determine a correlation between the estimates of the energy expenditure through these two protocols have identified limitations in transforming the counts in METs independently of the equation used (Croute, Churrila & Basset, 2006).

Our data show correlations between the METs of both protocols only for beach volleyball. Although the correlation was positive, it was weak, and the values found differed according to the classification of the intensity of the activity. According to the Actual METs, beach volleyball is on the superior level for classification of moderate activity. On the accelerometer, this activity is classified as moderate, but is close to the inferior limit of this classification (Garber et al., 2011).

This study has strengths and limitations. A strength was the use of three accelerometer placed in different anatomic places. According to the references explored, this is the first research with AVG to investigate the total volume of physical activity using three accelerometer. Another strength was the use of objective measure for the estimative of METs by indirect calorimetry.

Among the limitations of this research, the size and type of sample don’t allow generalizations to the adult population. Another limitation was the short timespan for play of each game and that each game was developed to be played at home, while our study was conducted in laboratory. The participants may have exerted more effort while playing because they knew they were being observed and participating in a study; it is possible that these conditions were not indicative of the reality of playing at home. Also, the transversal design of this study didn’t allow for controlling the influence of learning the game on the execution of motions.

Conclusion

To conclude, the values of counts and predicted METs were specific to each game and body location of the accelerometer. There was interaction between the games and the positioning of the accelerometer. In other words, the attachement site of the accelerometer, depending on the game, can interfere in the results of the total volume of the physical activity. Accelerometry does not seem to be the best method to assess energy expenditure (predicted METs). However, it can be used to quantify the volume of physical activity since its use with other anatomic attachement site better quantifies some physical activities and sports.

Conflicts of interest - The authors declare that they have no competing interest.

References

Althoff, .T, Socic, R., Hicks, J.L., King, A.C., Delp S.L., & Leskove, J. (2017). Large-scale physical activity data reveal worldwide activity inequality. *Nature*, *547*,336-339.

Clevenger, K.A. & Howe, C.A. (2016). Effect of prior game experience on energy expenditure during Xbox Kinect in children and teens. *Games for Health Journal*, *5*, 304-310.

Corder, K., Brage, S., & Ekelund, U. (2007). Accelerometers and pedometers: methodology and clinical application. *Current Opinion in Clinical Nutrition and Metabolic Care, 10*, 597-603.

Crouter, S.E., Churilla, J.R., & Bassett, D.R. Jr. (2006). Estimating energy expenditure using accelerometers. *European Journal of Applied Physiology, 98*, 601-612.

Cuberek, R., Fromel, R., Groffik, D, & Jakubec L. (2017). Differences between an accelerometer and a heart rate monitor in monitoring non-training-related load in adolescents: an opportunity to distinguish between the physical and mental load. *Journal of Physical Education and Sport, 17*,1139-1146.

Freedson, P.S., Melanson, E., & Sirard, J. (1998). Calibration of the computer science and applications, Inc. accelerometer. *Medicine and Science in Sports and Exercise,* 30, 777-781.

Garber, C.E., Blissmer, B., Deschenes, M.R., Franklin, B.A., Lamonte, M.J., Lee, I.M., … American College of Sports Medicine. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults. *Medicine and Science in Sports and Exercise*, 43, 1334-1359.

Graves, L.E., Ridgers N.D., Williams K., Stratton, G., Atkinson, G., & Cable, N.T. (2010). The Physiological cost and enjoyment of Wii Fit in adolescents, young adults, and older adults. *Journal of Physical Activity and Health*, 7, 393-401.

Graves, L.E., Ridgers, N.D., & Stratton, G. (2008). The contribution of upper limb and total body movement to adolescents energy expenditure whilst playing Nintendo Wii. *European Journal of Applied Physiology 104,* 617-623.

Hildebrand, M., Van Hees, V.T., Hansen, B.H., & Ekelund, U. (2014). Age group comparability of raw accelerometer output from wrist- and hip-worn monitors. *Medicine and Science in Sports and Exercise*, *46*, 1816-1824.

Kim, M., Angermann, J., Bebis, G., & Folmer. E. (2013). ViziCal: Accurate energy expenditure prediction for playing exergames. *Association for Computing Machinery,* 26, 397-404.

Kozey, S.L., Lyden, K., Howe, C.A., Staudenmayer, J.W., & Freedson, P.S. (2010). Accelerometer output and MET values of common physical activities. *Medicine and Science in Sports and Exercise,* 42, 1776–1784.

Loprinzi, P.D., & Smith, B. (2017). Comparison between wrist-worn and waist-worn accelerometry. *Journal of Physical Activity & Health, 14,* 539-545.

Lyden, K., Kozey, S.L., Staudenmeyer, J.W., & Freedson, P.S. (2011). A comprehensive evaluation of commonly used accelerometer energy expenditure and MET prediction equations. *European Journal of Applied Physiolology*, *111,* 187 -201.

Lyons, E.J., Tate, D.F., Bowling, J.M., Ribisl, K.M., Kayararaman, S. (2011). Energy expenditure and enjoyment during video game play: differences by game type. *Medicine and Science in Sports and Exercise, 1*0, 1987-1990.

Ndahimana, D. & Kim, E-K. (2017). Measurement methods for physical activity and energy expenditure: A review. *Clinical Nutrition Research, 6*, 68-80.

Ozemek, C., Kirschner, M.M., Wilkerson, B.S., Byun, W., & Kaminsky, L.A. (2014). Intermonitor reliability of the GT3X+ accelerometer at hip, wrist and ankle sites during activities of daily living. *Physiologial Measurement, 35*, 129-138.

Pinnington, H.C., Wong, P., Tay, J., Green, D., & Dawson, B. (2001). The level of accuracy and agreement in measures of FEO2, FECO2, and VE between the Cosmed K4b2 portable, respiratory gas analysis system and a metabolic cart. *Journal of Science and Medicine in Sport*, *4*, 324–325.

Rosenberger, M.E, Haskell, W.L., Albinali, F., Nawyn, J. & Intille. S. (2013). Estimating activity and sedentary behavior from an accelerometer on the hip or wrist. *Medicine and Science in Sports and Exercise,45,* 964-975.

Sell, K., Lillie, T., & Taylor, J. (2008). Energy expenditure during physically interactive video game playing in male college students with different playing experience. *Journal of American College Health, 56*, 505-512.

Taylor, L.M., Maddison, R., Pfaeffli, L.A., Rawstorn, J.C., Gant, N., & Kerse, N.M. (2012). Activity and energy expenditure in older people playing active video games. *Archives of Physical Medicine and Rehabilitation, 93*, 2281-2286.

Tripette, J., Ando, T., Murakami, H., Yamamoto, K., Ohkawara, K., Tanaka, S., & Miyachi, M. (2014). Evaluation of active video games intensity: comparison between accelerometer-based predictions and indirect calorimetric measurements. *Technolology and Health Care, 22*, 199-208.

Tudor-Locke, C., Barreira, T.V., & Schuna, J. (2015). Comparison of step outputs for waist and wrist accelerometer attachment sites. *Medicine and Science in Sports and Exercise, 47*, 839-842.

Verloigne, M., Loyen, A., Van Hecke, L., Lakerveld, J., Hendriksen, I., De Boudheaudhuij, I., … van der Ploeg, H.P. (2016). Variation in population levels of sedentary time in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. *International Journal of Behavioral Nutrition and Physical Activity* , 13 13:69.