<<< Research Report >>>

Physical Activity Levels, Perceived Effort and Affect in Hungerball

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1. Background and Statement of Research Aims

Physical activity plays an important role in maintaining health and well-being in children and adults, with low levels of physical activity being associated with a higher prevalence of psychological complaints, increased risk for disease (e.g., obesity, cardio-vascular disease), and increased mortality (Warburton et al. 2006 & Jennson & LeBlanc 2010). Vice versa, robust evidence exists to suggest that regular physical activity can help prevent these negative outcomes.

In order to sustain health and well-being, the World Health Organization (2010) recommends adults obtain at least 150 minutes of moderate-intensity aerobic physical activity or 75 minutes of vigorous-intensity physical activity each week. Muscle-strengthening activities that involve major muscle groups should also be undertaken at least twice per week. Children and youth (5-17yrs) should accumulate at least 60 minutes of moderate to vigorous physical activity each day and they should undertake activities that strengthen bone and muscle at least 3 times per week (World Health Organization 2010). In New Zealand, around 50.2% of all adults report undertaking enough weekly physical activity to meet the WHO guidelines. Over 1 in 10 adults (13.4%) report undertaking little to no exercise (<30 minutes) in the seven days before being surveyed. Further, Asian and Pacific adults and adults living in socioeconomically deprived areas were less likely to be physically active (Ministry of Health 2018). New Zealand children are even less likely to meet WHO physical activity guidelines. Smith et al., 2018 reported that only 7% of 5 to 17 year olds meet the WHO physical activity guidelines based on the Active NZ Survey. These values improve to 38% of New Zealand children (8-13yrs) and 39% of youth (13-18yrs) when regional accelerometery-based data sets are examined, but still underscore the fact that many children fail to accumulate sufficient daily physical activity. An emerging concept is that development of physical literacy during childhood facilitates participation in higher physical activity throughout the life span (Whitehead 2001). Although it is generally felt that physical literacy is falling in children and adults, work to facilitate physical literacy development in New Zealand and Australian children is the focus of many educational policies and research (Tremblay et al. 2018 and Tompsett et al. 2014).

Activities that promote physical activity and physical literacy may be incredibly important in maintaining long-term health and wellbeing. Activities that are engaging while also providing appropriate activity intensity and physical literacy development are important to identify. People are much more likely to participate in physical activity that is "fun" or aligns with intrinsic motivators vs. when it viewed as formal exercise undertaken solely for health or fitness benefit; especially if they are unaccustomed to participation in formal or structured exercise (Teixeira et al. 2012). Thus, in order to increase physical activity levels among the population it is important to identify sports and activities that contribute to the recommended amount of moderate and/or vigorous activity but which, at the same time, are also accessible and enjoyable. The current monitoring study aimed to assess physical activity levels, perceived effort and enjoyment in a new ball sport called 'Hungerball'.

Hungerball is a ball sport that is played in an inflatable arena with six goals. Depending on the game type, six players each defend their own goal whilst attempting to score goals against the other players. The game was originally designed based on football (i.e., one ball, no hands) but has recently extended to incorporate other game variants (e.g., body-ball, hockey). The game can be played in singles format (6x1 player) as well as teams format (e.g., 2x3 players), and promises high levels of engagement regardless of age, gender and experience (www.hungerball.com).

The current study was issued by Hungerball Ltd. (Auckland, New Zealand) and carried out by researchers from the University of Auckland (Department of Exercise Sciences) to create an initial evidence base regarding physical activity and enjoyment levels in Hungerball. Research aims were as follows:

1. To quantify physical activity, perceived effort and affect in Hungerball
2. To compare physical activity levels, perceived effort and affect (a) between different age groups (children, adolescents, and adults) and (b) between different game types (soccer-individual, soccer teams, and body-ball singles.
3. To establish correlations between various player characteristics (e.g., age, height, weight, soccer experience) and the different outcome variables.

2. Research Methodology

2.1. Participants

Thirty-five healthy participants volunteered to participate in the current study. Participants were recruited amongst children (aged 6-12; n = 14), adolescents (aged 13-17; n = 7) and adults (aged >18; n = 14) participating in three organized Hungerball Ltd. events across October-December 2019. Prior to participation, all participants completed the Physical Activity Readiness Questionnaire (PAR-Q; Thomas et al. 1992). No contra-indications to engage in physical activity were identified. In addition, participants completed a brief questionnaire asking them to report their gender, age, and perceived soccer experience (7-point scale; 1 = not experienced at all; 7 = very experienced). Finally, on-site measurements of participants' height (in cm) and weight (in kg) were taken. Table 1 provides an overview of all participant descriptives.

***Table 1.* Overview of participant descriptives.**

	Children		Adolescents		Adults	
	M	*SD*	*M*	*SD*	*M*	*SD*
n	14	-	7	-	14	-
gender (male/female)	11/3	-	7/0	-	12/2	-
age (years)[b,c]	9.9	*1.7*	14.6	*1.4*	39.6	*11.7*
height (cm)[a,b]	139.1	*10.9*	168.6	*13.0*	177.0	*7.5*
weight (kg)[a,b,c]	34.8	*7.9*	54.0	*11.1*	83.1	*14.7*
BMI (kg/m^2)[b,c]	17.9	*2.8*	18.8	*1.7*	26.4	*3.6*
soccer experience (1-7)	4.0	*1.7*	4.9	*1.3*	4.9	*2.0*

Note. [a] children significantly different from adolescents; [b] children significantly different from adults; [c] adolescents significantly different from adults (one-way ANOVA; $p < .05$).

As can be seen in Table 1 – and based on recruitment taking place from amongst pre-defined age groups (children, adolescents, adults) – participants in the different age groups differed significantly with regards to most descriptive measures but not with regards to their perceived soccer experience, which for each group averaged around a score of '4' to '5' (average to slightly above average). Notably, group sizes were variable, with fewer participants recruited into the 'adolescents' group.

2.2. Research Design

The study had a within-between design, allowing to distinguish between physical activity, perceived effort and affect levels amongst different age groups (i.e., children, adolescents and adults; between subjects) and game types (i.e., soccer-singles, soccer-teams and body-ball / hockey singles; within subjects).

Participants were tested within their respective age groups and participated in a single 60-minute Hungerball session that was subdivided into shorter segments of different Hungerball games. Games played included: (i) *soccer singles* (6 x 1 player); (ii) *soccer teams* (2 x 3 players); and (iii) either *body-ball singles* (6 x 1 player) or *hockey singles* (6 x 1 player).

For each game type, the study made use of a standard inflatable Hungerball arena (Hungerball Ltd., Auckland, New Zealand; see Figure 1). The standard Hungerball arena has a diameter of 12 meters and counts 6 goals that are defended by a total of 6 players (i.e., one player per goal).

2.2.1. Soccer Singles

For the soccer singles game (6 x 1 player), each player attempts to score in any of the other five goals whilst defending their own goal against attempts from the other players. One ball, no hands. When a player concedes a goal (i.e., is scored against) they leave the arena and are replaced by the next player in line.

2.2.2. Soccer Teams

For the *soccer teams* game (2 x 3 players), three players with adjacent goals team up and play against the other three players defending the remaining three goals (i.e., three goals per team). One ball, no hands. When a team concedes a goal (i.e., is scored against) they leave the arena and are replaced by the next team in line.

2.2.3. Body-Ball Singles

For the *body-ball singles* game type (6 x 1 player), rules are the same as for the soccer singles game type, except that players can now touch the ball with any part of their body.

2.2.4. Hockey Singles

For *hockey singles* games (6 x 1 player), rules are again the same as for the soccer singles game type, except that a smaller (hockey) ball is used and players play the ball with a hockey stick. Swatting or kicking the ball using hands or feet is not permitted for goal scoring.

In all cases rules were maintained as stipulated by the Hungerball International Federation (IHF; www.hungerball.com/rules).

Figure 1. **Inflatable Hungerball Arena.**

2.3. Materials and Dependent Measures

2.3.1. Physical Activity

Physical activity was objectively measured during Hungerball game play using accelerometry and heart rate recording.

Each participant was fitted a triaxial accelerometer (Actigraph GT3x; Actigraph Corp; Pensacola FL USA) that was worn around the waist and positioned over the right hip. The device measured and recorded displacement and velocity of movement occurring in three axial planes (vertical, horizontal, and perpendicular to both). The measurement sampling rate was set to 30Hz and data were summed into 10 second recording epochs. The measured movement is recorded as a "count" value for each 10 second epoch based on a signal originating from piezoelectric sensors. A "count" theoretically represents a motion vector (acceleration and displacement) but the measure is unitless do to bandwidth filtering applied during measurement to filter out non-human movement signals arising from the piezoelectric movement sensors. This filtering makes it impossible to derive velocity from the final signal (Actigraph Corp). Participants were also fitted with a heart rate strap and monitor (Polar M400 & H7; NSW Australia). The heart rate strap and monitor measure bioelectric signals generated by the heart and uses a 5 second rolling average to report heart rate in beats per minute.

2.3.2. Perceived Effort and Affect

Perceived effort and affect across the entire 60-minute Hungerball session were assessed immediately upon finishing the last of the three games, based on a paper-pencil session Rating of Perceived Exertion (sRPE) and a session rating for negative/positive affect, respectively.

Participants' sRPE was obtained using a modified 10-point Borg Scale, ranging from 1 (not tired at all) to 10 (very tired) (Hayward & Gibson 2014; see Appendix 1). Session ratings for negative/positive affect were obtained using the 11-point Feeling Scale (FS), ranging from -5 ('very bad') to +5 (very good) (Hardy & Rejeski, 1989; see Appendix 2).

2.4. Data processing and statistical analyses

2.4.1. Data processing

Accelerometry data was uploaded to a laptop computer (Dell, Latitude, Auckland NZ) immediately upon finishing the last of the three games and processed off-line using ActiLife version 6.13.4 software (Actigraph Corp, Pensacola FL USA). Time filters truncated each data file to match the Hungerball session length for each participant. Additional time filters were used so that the data collected for each game duration could be processed independently. Well established cutpoints (Table 2) were used to identify count values that represented different physical activity intensity levels in adults (Freedson et al. 1998) and children

(Freedson et al. 2005). The number of epochs with count values matching each physical activity intensity band were summed to derive the total amount of time spent active during game play at each activity level.

Table 2: **Accelerometry cutpoints for exercise intensity classification**

	Children[a]		**Adults[b]**	
Activity Classification	Minimum (CPM)	Maximum (CPM)	Minimum (CPM)	Maximum (CPM)
Sedentary	0	149	0	99
Light	150	499	100	1951
Moderate	500	3999	1952	5724
Vigorous	4000	7599	5725	9498
Very Vigorous	7600	≥ 7601	9499	≥ 9500

Note: Values taken from [a]Freedson et al. 2005 and [b]Freedson et al. 1998. CPM: Counts·min^{-1}

Heart rate data from each monitor were uploaded to a laptop (Dell, Latitude, Auckland NZ) after finishing the last game of the Hungerball session. Data were exported in spreadsheet files (Excel, Microsoft Corp) and truncated to the Hungerball game and session length. As absolute heart rate values are difficult to interpret when collected from participant pools that varied widely in age, (6 to 53 yrs.), heart rate data are reported as a percentage of the age-predicted maximum heart rate. For children and adolescents, a value of 194 beats per minute is more accurate than using standard heart rate maximum prediction equations (Verschuren et al. 2011). Thus, for children and adolescent participants heart rate was calculated using the following formula:

$$Percentage\ of\ age\ predicted\ \max HR_{children} = \frac{measured\ HR}{194}\ x\ 100$$

For adults, the percentage of the age-predicted maximum heart rate was calculated using the Tanaka et al (2001) equation:

$$Percentage\ of\ age\ predicted\ \max HR_{adults} = \frac{measured\ HR}{208-(0.7\ x\ age)}\ x\ 100$$

Questionnaire Data (sRPE and FS) were copied into Microsoft Excel and, as described above, reflected perceived effort and affect across the entire 60-minute Hungerball session (i.e., no separate ratings were taken for the different game types).

2.4.2. Statistical Analyses

To quantify physical activity, perceived effort and affect in Hungerball (*aim 1*), means, standard deviations and 95% confidence intervals were calculated for all dependent variables across the different age groups and game types. Comparisons between different age groups and game types (*aims 2a and 2b*) were analysed with one-way ANOVAs and conducted separately for each dependent variable. Finally, to establish correlations between measures (*aim 3*), Pearson correlation coefficients (*r*) were calculated. For all statistical analyses, $p < .05$ was considered statistically significant.

3. Results

3.1. Physical Activity Levels, Perceived Effort and Affect

3.1.1. Activity Monitoring

Table 3 presents the total time (minutes) for each Hungerball session and each Hungerball game for the three age groups studied. All three groups played soccer singles for 20 minutes but not all groups played each of the 4 games or played them for the same length of time.

Table 3. Active Playing Time

	Children	**Adolescents**	**Adults**
Playing Time (minutes)			
Overall Session	40	40	51
Soccer Singles	20	20	20
Soccer Teams	20	10	20
Body-Ball Singles	-	10	-
Hockey Singles	-	-	11

Table 4 presents physical activity intensity data measured during each Hungerball session and game played by the different age groups. Importantly, physical activity monitoring spanned the entire game play period and, as a result, includes active play (i.e., in the arena) as well as rest (e.g., waiting for turn, pre-game instruction). In general, there was little difference in most measurements of physical activity intensity between the 3-age groups (Table 4). Similar mean session and game MET levels were measured by accelerometry, where 1MET is equivalent to an energy expenditure rate at rest of $1 kcal \cdot kg^{-1} \cdot hr^{-1}$ or 3.5ml of oxygen consumption per kg of body weight per minute (i.e., thus, a 3MET activity means it has an energy expenditure rate that is 3 times greater than the resting rate). The total number of steps accumulated during play is in part dependent on the length of time each game is played. Only *Soccer Singles* was played for the same length of time by all 3 age groups and there was no difference between the groups for total steps. Although the number of steps accumulated by the adolescent-age group during *Soccer Teams* play appears lower vs. other games and age groups, it is not. The adolescent group only played *Soccer Teams* for 10 minutes and would likely accumulate the same total steps as the other age groups if the adolescent group had played for 20 minutes. *Body-ball Singles* and *Hockey Singles* also appear to have lower step counts but this is also due to the shorter length of play (i.e., approximately 10 minutes). Based on the MET rate, step rate and heart rate during play, the intensity of play for these games was likely similar for all age groups except for *Hockey Singles* in the adults (Table 4). During *Hockey* play, significantly lower MET values and stepping rates were measured despite recording heart rates similar to other games and to measurements made in the other age groups.

Table 4. Measures of Physical Activity Intensity during Hungerball Play Across Different Games and Age-Groups

	Children		**Adolescents**		**Adults**	
	M(SD)	*95% CI*	*M(SD)*	*95% CI*	*M(SD)*	*95% CI*
Metabolic Equivalent of the Task (MET)						
Overall Session	3.5(0.6)*	3.2;3.9	3.3(0.4)	2.9;3.8	3.2(0.7)	2.9;3.4
Soccer Singles	3.5(0.7)*	3.1;3.9	3.2(0.4)	2.8;3.6	3.7(0.4)*	3.2;4.1
Soccer Teams	3.6(0.6)*	3.2;4.0	3.3(0.4)	2.9;3.7	3.8(0.6)*	3.4;4.1
Body-Ball Singles	--	--	3.5(0.6)	3.0;4.1	--	--
Hockey Singles	--	--	--	--	2.1(0.5)[b]	1.8;2.4
Number of Steps Accumulated						
Overall Session	1328(249)	1184; 1471	1330(195)	1512; 1932	1459(339)	1255; 1664
Soccer Singles	641(145)	557;725	758(133)	635;881	617(201)	495;738
Soccer Teams	687(154)	597;776	392(41)[c]	354;430	611(155)	518;705
Body-Ball Singles	--	--	180(42)[d]	142;219	--	--
Hockey Singles	--	--	--	--	232(81)[b]	183;281
Stepping Rate (steps·min^{-1})						
Overall Session	33(6)	30;40	38(6)	33;43	28(6)[a]	24;31
Soccer Singles	32(7)	28;36	38(7)	32;44	31(10)	25;37
Soccer Teams	34(8)	30;39	39(4)	35;43	31(8)	26;35
Body-Ball Singles	--	--	36(8)	28;44	--	--
Hockey Singles	--	--	--	--	21(7)[b]	17;26
Average Heart Rate (% of age-predicted max)						
Overall Session	76(6)	73;79	79(5)	75;83	75(7)	72;77
Soccer Singles	74(6)	69;78	79(6)	69;89	71(9)	65;77
Soccer Teams	79(5)	75;83	79(7)	62;96	78(6)	74;82
Body-Ball Singles	--	--	80(1)	77;82	--	--
Hockey Singles	--	--	--	--	75(5)	71;78

Note: mean (M); standard deviation (SD); 95% confidence interval (95%CI); *MET value significantly greater than 3METs *(threshold for moderate intensity physical activity; one sample t-test; p<.05)*; [a] Adults different from Children and Adolescent groups; [b] Hockey different from soccer singles and teams within age-group; [c] Soccer Teams different from soccer singles; [d] Body-ball different from soccer singles and teams within age group (one-way ANOVA; $p < .05$).

Table 5 presents the proportion of time spent at each activity level for each of the different age groups, across the entire Hungerball session as well as for each different game type.

Table 5. Proportion of Session & Game Time (% of total) Spent at Each Activity Intensity

	Children		Adolescents		Adults	
	M(SD)	*95%CI*	*M(SD)*	*95%CI*	*M(SD)*	*95%CI*
Sedentary (%)						
Overall Session	37(13)	32;42	24(10)[a]	19;28	35(13)	31;39
Soccer Singles	39(14)	30;47	26(8)	18;34	34(13)	26;42
Soccer Teams	36(14)	29;43	25(8)	17;32	31(10)	25;37
Body-Ball Singles	--	--	20(13)	9;32	--	--
Hockey Singles	--	--	--	--	39(14)	30;47
Light (%)						
Overall Session	11(5)	9;13	11(5)	8;13	37(10)[b]	33;40
Soccer Singles	12(6)	8;15	12(6)	6;17	36(10)[b]	30;43
Soccer Teams	10(3)	8;12	8(3)	5;10	38(10)[b]	32;44
Body-Ball Singles	--	--	13(5)	8;17	--	--
Hockey Singles	--	--	--	--	35(10)	29;41
Moderate (%)						
Overall Session	35(9)[c]	31;39	46(9)[a]	42;50	26(9)[b]	23;29
Soccer Singles	33(9)	27;38	44(6)	38;50	25(9)	20;31
Soccer Teams	37(9)	32;42	50(5)	45;55	28(10)	22;34
Body-Ball Singles	--	--	44(14)	31;57	--	--
Hockey Singles	--	--	--	--	24(10)	19;30
Vigorous (%)						
Overall Session	16(5)	14;18	18(5)	16;20	3(4)[b]	1;4
Soccer Singles	16(4)	13;18	17(4)	13;21	4(5)[b]	0;7
Soccer Teams	16(6)	12;19	17(6)	12;23	3(4)[b]	0;6
Body-Ball Singles	--	--	20(5)	15;24	--	--
Hockey Singles	--	--	--	--	2(1)	1;2
Very Vigorous (%)						
Overall Session	2(2)	0;2	2(2)	1;3	0	0
Soccer Singles	1(1)	0;2	1(2)	0;3	0	0
Soccer Teams	2(3)	0;4	1(1)	0;1	0	0
Body-Ball Singles	--	--	3(3)	0;6	--	--
Hockey Singles	--	--	--	--	0	0

Note: mean (M); standard deviation (SD); 95% confidence interval (95%CI); [a] adolescents different from children and adults; [b] adults significantly different from children and adolescents; [c] children different from adolescents and adults (one-way ANOVA; $p < .05$).

It should be noted that "traditional" accelerometry-based physical activity level descriptors (e.g., sedentary, light, moderate etc.) were used to categorize the intensity of Hungerball play in Table 5. The term "sedentary" reflects measurement of low magnitude movements where as “vigorous” reflects large magnitude movements according to the accelerometry counts recoded during play (see Table 2 for accelerometry count value cut points). When viewed this way, Table 5 shows the variable and intermittent nature of Hungerball game play as it sums the amount of time during game play associated with movement of different intensity magnitude. During game play, there are moments of fast accelerations (e.g., vigorous) and moments where the body mass is more or less stationary (e.g., sedentary). Thus, Hungerball game play is a non-steady state, high intensity interval exercise like soccer rather than a continuous exercise such as running or jogging.

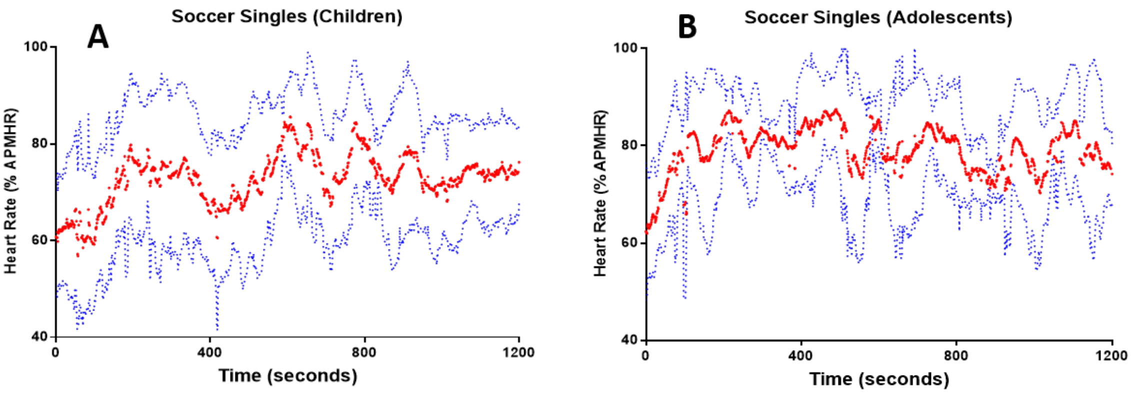
Table 5 shows that in general, adolescents spent the least amount of the total session and individual game play time performing low magnitude movement (i.e., “*sedentary*”) and the most game play time performing moderate to vigorous movements (Table 5). Specifically, adolescents performed significantly more moderate to vigorous movement during the overall session (65.6±10.4%; 95%CI: 60.9 to 70.4%) than the children (52.1±11.3%; 95%CI: 47.7 to 56.4%) and adults (24.8±11.5%; 95%CI: 24.8 to 32.3%; $p<0.05$).

Table 5 is quite important for understanding the dynamics of Hungerball game play. Although partitioning of movement intensity was not overtly different between different game types, there were clear differences between groups in terms of time spent active at moderate to vigorous intensities during each session. The adolescent group spent 60 to 70% of their Hungerball session active with moderate to vigorous intensity movement whereas the adults were moving at these intensities only 25 to 32% of the session time. One possible explanation could be group size. The adolescent group had $n=7$ participants compared to the adults with $n=14$. The smaller group may have resulted in players rotating in and out of game play faster ensuring greater time spent playing versus waiting to get back in the arena. The physical activity profile of the adolescent group likely reflects what the exercise activity and intensity profile looks like for someone playing Hungerball continuously for 40 to 60 minutes.

3.1.2. Activity Intensity Profile of Hungerball Play

Figure 2 (next page) shows the heart rate profile for children (A), adolescents (B) and adults (C) playing *Soccer Singles* for 20 minutes. Physical activity profiles as measured by accelerometry are shown for a representative boy and girl participant from the children group playing *Soccer Singles* and *Soccer Teams* (Figure 3); two male adolescent players with differing levels of moderate to vigorous activity time (Figure 4); and for an adult participant playing both soccer games along with *Hocke*y (Figure 5). Unfortunately, comparisons between all age groups across all games is not possible due to differences in games played as well as differences in game length. In spite of this limitation, data presented in Figures 2 thru 5 are important because they highlight the variable nature of Hungerball game play intensity.

Figure 2 shows that heart rate approached near maximal levels during moments of game play and, more importantly, that heart rates were typically sustained above 60% of the age-predicted maximum (i.e., within the training zone [50 to 80% HR max] for aerobic improvement) across all three age groups. Given there were no significant differences in mean heart rate between games within groups, or between different games played by the different groups, the heart rate profiles presented in Figure 2 likely provides an adequate reflection of the heart rate responses of all the Hungerball games and sessions. Further, although Hungerball by nature requires intermittent movements of differing intensity, the heart rate response increases and remains stable reflecting a sustained stimulus to the cardiovascular system. Thus, Hungerball play provokes a cardiovascular response of sufficient intensity and duration to promote aerobic conditioning across all age groups studied.



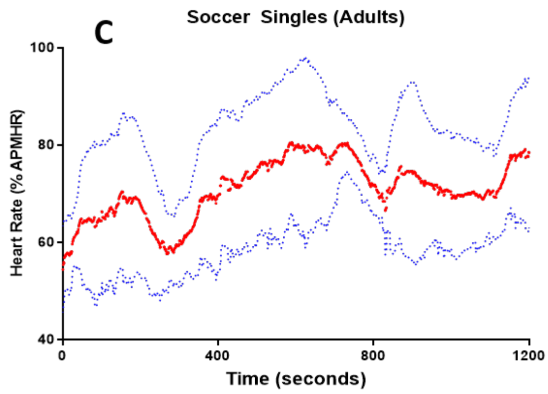


Figure 2. The mean (red dots) and standard deviation (blue dots) for the heart rate response of children (**A**), adolescents (**B**) and adults (**C**) playing *Soccer Singles* for 20 minutes. Heart rate data is expressed as a percentage of the age-predicted maximum heart rate (%APMHR) as described in the Methods

There were too few female participants recruited to examine the effect of gender on Hungerball game play. Figure 3 (next page) shows representative traces recorded for a male and female participant from the children group. The female participant showed slightly reduced count values across all 3-axis planes during game play with more frequent play breaks. In general, this pattern of reduced game play by female participants in all age groups across all individual games was apparent and it is consistent with previous studies; especially those focused on children and physical activity (Brockman 2010). Girls tend to play less vigorously than boys and this difference becomes greater with age.

Figure 4 (next page) compares the accelerometry profiles of adolescent participants that accumulated different amounts of moderate to vigorous activity intensity during game play. The participant accumulating more time active at moderate to vigorous intensity clearly shows fewer instances of accelerometry counts returning to baseline and more numerous and larger spikes of activity above the "vigorous" cut point. Between group comparisons of accelerometry profiles can be made by visual comparison of Figure 3 (children), Figure 4 (adolescents) and Figure 5 (adults; pg. 15).

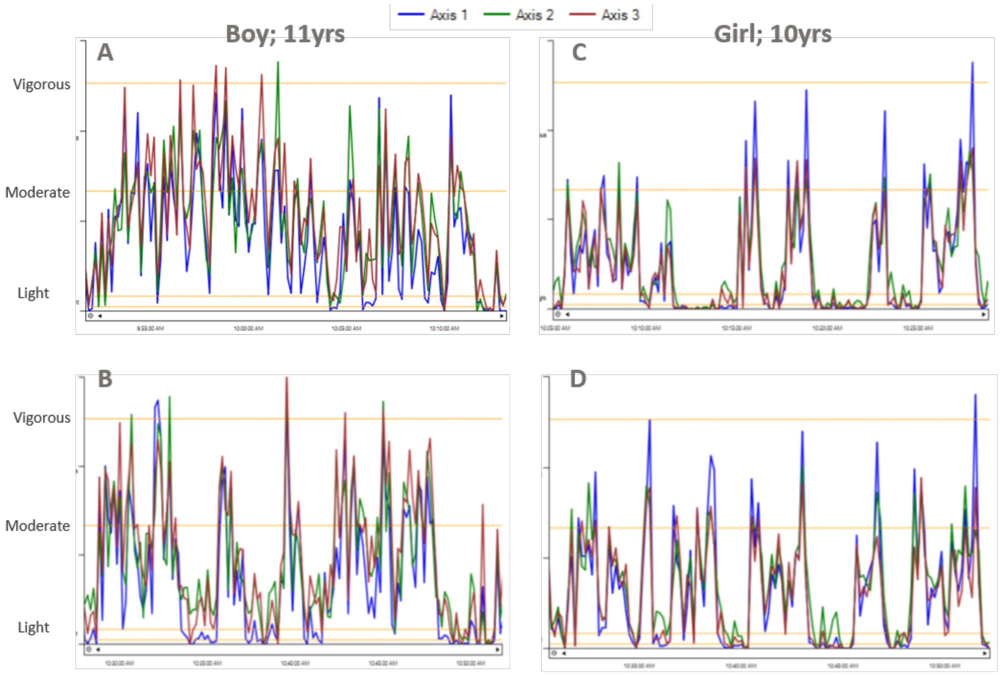


Figure 3. Accelerometer count data from representative children participants playing Soccer Singles (**A & C**) and Soccer Teams (**B & D**). Activity counts are reported for 3 different axial planes of movement (blue line, vertical; green line, horizontal; red line, perpendicular to axis 1 & 2). The yellow lines on each graph mark the count cut points for light, moderate and vigorous intensity physical activity.

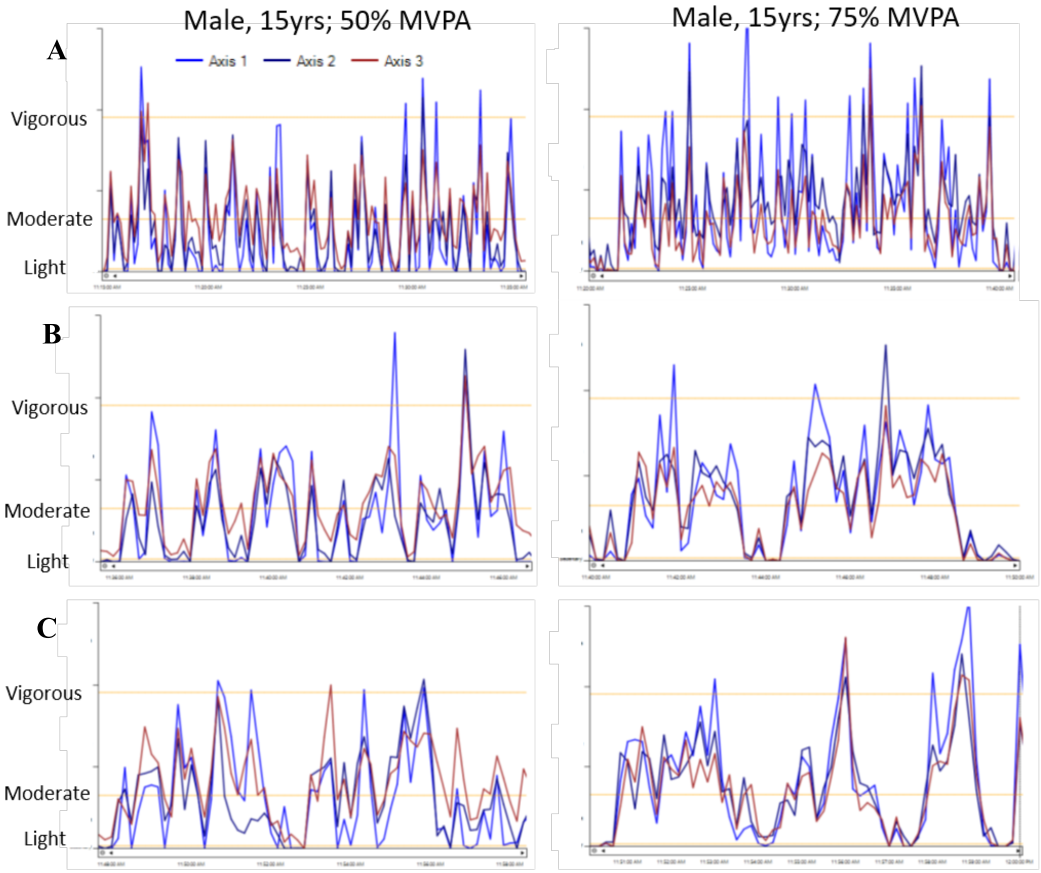


Figure 4. Accelerometer count data from two adolescent participants accumulating low amounts (50%MVPA) and high amounts (75%MVPA) of vigorous activity in Soccer Singles (**A**), Soccer Teams (**B**) and Body Ball Singles (**C**). Activity counts reported as in Figure 3, above.

Adult

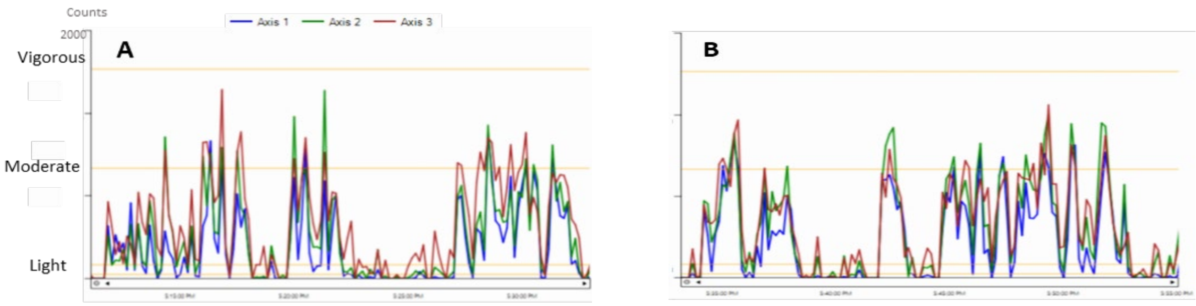


Figure 5. Shows accelerometer count data collected from a representative adult participant while playing Soccer Singles (**A**), Soccer Teams (**B**) and Hockey Singles (**C**). Activity counts are reported for 3 different axial planes of movement (blue line, vertical plane; green line, horizontal plane; and red line, perpendicular to axis 1 & 2). The yellow lines on each graph mark the count cut points for light, moderate and vigorous intensity physical activity

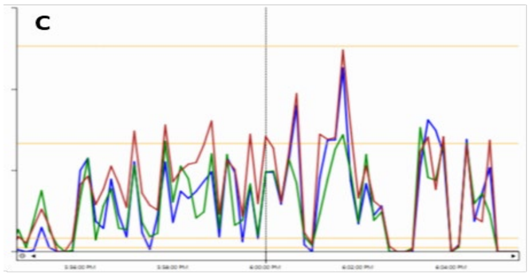


Table 6 (next page) shows accelerometer counts for each of the 3-axis planes as measured by accelerometry.

Interestingly, as can be derived from Table 6, the movements involved in Hungerball game play occur almost equally in all three motion planes. This 3-dimensional movement pattern is in stark contrast to other "traditional" forms of exercise such as running, where movement occurs mostly in two planes (vertical and horizontal). The data highlight that Hungerball play requires players to make rapid accelerations and decelerations in multiple movement planes. Thus, in addition to the cardiovascular benefit provided by muscular movement, Hungerball game play provides challenging neuromotor training stimuli. Hungerball play requires agility in that the participant's centre of mass must be rapidly accelerated and decelerated in a controlled manner to move the body about the game arena. Furthermore, limb movement must be controlled to block or kick the ball into the opponent's goal. These complex movement patterns require dynamic control over balance, flexibility, mobility, muscle strength, power and endurance. Controlling centre of mass and limb movements through space requires motor control and development and practice of this ability is central to attaining/maintaining physical literacy (Edwards et al. 2017).

Table 6. Accelerometry Axis Counts (counts·min^{-1}) during Hungerball Play

	Children		Adolescents		Adults	
	M(SD)	*95% CI*	*M(SD)*	*95% CI*	*M(SD)*	*95% CI*
Axis 1 (Vertical)						
Overall Session	1413(552)	1190;1635	2087(434)	1890;2285	1337(520)	1168;1505
Soccer Singles	1405(628)	1025;1784	1943(415)	1559;2327	1405(628)	1025;1784
Soccer Teams	1421(490)	1125;1717	2059(389)	1699;2419	1421(490)	1125;1717
Body-Ball Singles	--	--	2261(493)*	1804;2717	--	--
Hockey Singles	--	--	--	--	1185(429)	926;1445
Axis 2 (Horizontal)						
Overall Session	1950(393)	1798;2103	2250(449)	2046;2455	1675(504)	1512;1839
Soccer Singles	1884(371)	1669;2098	2064(328)	1761;2368	1670(519)	1356;1983
Soccer Teams	2017(416)	1777;2257	2253(341)	1938;2569	1799(434)	1537;2060
Body-Ball Singles	--	--	2434(605)	1874;2994	--	--
Hockey Singles	--	--	--	--	1557(563)	1217;1897
Axis 3 (Perpendicular)						
Overall Session	1958(488)	1768;2147	2311(432)	2114;2507	1975(815)	1711;2239
Soccer Singles	1935(540)	1623;2247	2053(315)	1762;2344	1967(873)	1439;2496
Soccer Teams	1980(449)	1721;2239	2294(441)	1887;2702	2162(889)	1625;2699
Body-Ball Singles	--	--	2584(404)*	2211;2958	--	--
Hockey Singles	--	--	--	--	1797(691)	1379;2214
Vector Magnitude						
Overall Session	3405(718)	3127;3684	3999(631)	3711;4286	3058(958)	2747;3368
Soccer Singles	3328(730)	2907;3749	3664(429)	3268;4061	3083(1063)	2440;3726
Soccer Teams	3483(724)	2907;3749	3953(586)	3411;4495	3301(932)	2440;3726
Body-Ball Singles	--	--	4379(705)*	3726;5031	--	--
Hockey Singles	--	--	--	--	2790(875)	2261;3319

Note: mean (M); standard deviation (SD); 95% confidence interval (95%CI). For ease of comparison between groups playing different games or playing for different durations, data are presented as counts·min^{-1} (total counts divided by length of play). Vector Magnitude (VM) is a 3 dimensional movement measurement calculated from each of the 3 movement axis using the following formula: $VM = \sqrt{(axis\ 1)^2 + (axis\ 2)^2 + (axis\ 3)^2}$. The asterisk (*) identifies value different from Soccer Singles within an age-group (one-way ANOVA; $p < .05$).

3.1.3. Perceived Effort and Affect

Table 7 presents the means (M) and standard deviations (SD) for participants sRPE and FS score (negative/positive affect), for each of the different age groups, across the entire 60-minute Hungerball session.

Table 7. Perceived Effort and Affect

	Children		Adolescents		Adults		Total Sample	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
RPE (1-10)[b,c]	3.1	*2.5*	3.1	*1.1*	5.7	*2.3*	4.1	*2.5*
FS (-5/+5)	3.2	*1.7*	4.1	*0.7*	3.8	*1.2*	3.6	*1.4*

Note: sRPE = session Rating of Perceived Exertion; FS = Feeling State; [a] children significantly different from adolescents; [b] children significantly different from adults; [c] adolescents significantly different from adults (one-way ANOVA; $p < .05$).

In terms of physical effort, the sRPE for the children and adolescent groups was 3 out of 10 which is consistent with a "light" intensity physical activity (Hayward and Gibson 2014 and Norton et al. 2010). Adults rated Hungerball play slightly higher at 4 out of 10 which is consistent with a "moderate" activity intensity (Tables 4 and 5; Figures 3, 4 and 5). The ANOVA conducted on participants sRPE scores indicated that the observed differences between adults and children/adolescents were significant (Figure 6).

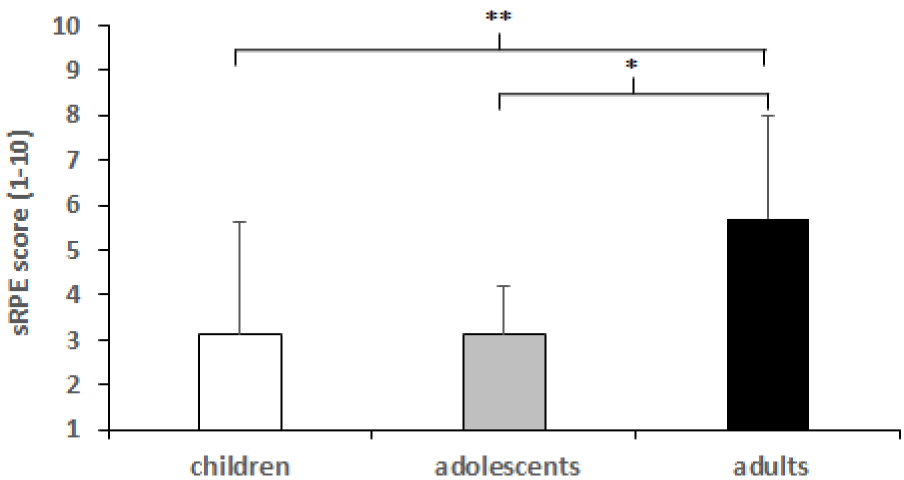


Figure 6. Age group differences in session Rating of Perceived Exertion (sRPE). * $p < .05$; ** $p < .01$.

The ANOVA conducted on participants' FS scores indicated that – in reflecting on the entire 60-minute Hungerball session (i.e., regardless of game types) – there were no significant differences in negative/positive affect ratings of children, adolescents and adults (all *p*'s > .16). On average, participating in Hungerball felt '*good*' to '*very good*', with none of the participants scoring below 0 ('*neutral*') (cf. Hardy & Rejeski, 1989).

In terms of negative/positive affect, the FS score for the total sample indicates that, on average, participants felt '*good*' to '*very good*' whilst playing Hungerball, with none of the participants scoring below 0 ('*neutral*') (Table 7 and Figure 7; Hardy & Rejeski, 1989).

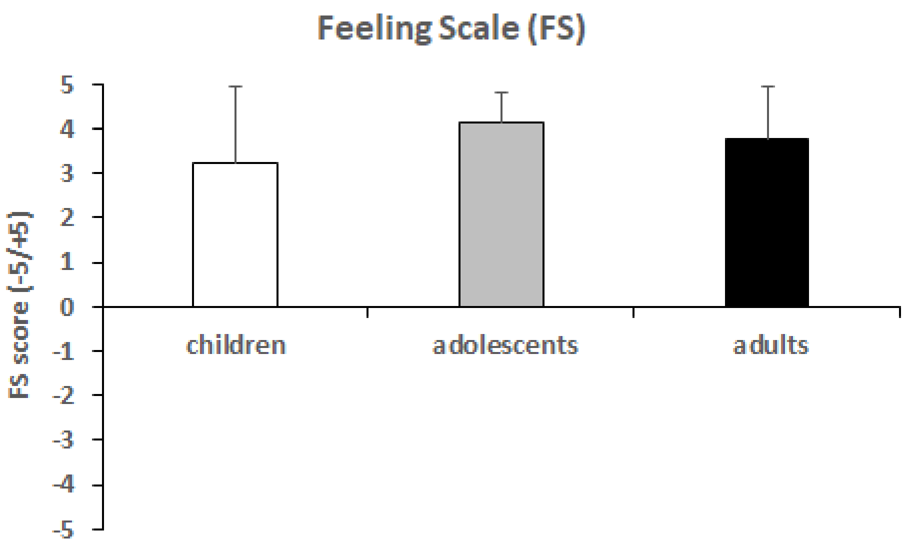


Figure 7. Age group differences in Feeling State (FS) scores.

3.2. Correlations between Dependent Measures

Pearson correlation coefficients between each of the participant descriptives, measures of physical activity and perceived effort and affect are reported in Table 8 (next page). As can be seen in Table 8, and in line with the observed age-group effects (see Table 5), higher age, weight and BMI correlated with a lower stepping rate, more activity in light intensity zones and less activity in higher intensity zones, whilst reporting higher levels perceived exertion (sRPE).

Interestingly, soccer experience did not show significant correlations with any of the measured activity and enjoyment variables (see Table 8), suggesting that skill or experience in soccer play don't seem necessary to find Hungerball game play enjoyable or engagement in (and benefit from) the activity intensity. As such, Hungerball appears to provide an engaging physical activity for children and adults that provides a cardiovascular training stimulus along with a neuromuscular stimulus that uses predominately primary movement patterns that would allow for development, refinement and maintenance of physical literacy across the lifespan.

Due to the skewed gender ratio within and between age groups, no correlations were calculated for gender.

Table 8. Pearson correlation coefficients among all measured variables for the overall Hungerball Session.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Descriptives																		
1	Gender (male/female)	1																
2	Age (years)	-	1															
3	Height (cm)	-	.65*	1														
4	Weight (kg)	-	.79*	.89*	1													
5	BMI (kg/m^2)	-	.78*	.66*	.92*	1												
6	soccer experience (1-7)	-	.25	.32	.38*	.37*	1											
Activity Intensity Measures																		
7	Ave METs	-	-.22	-.29	-.24	-.18	-16	1										
8	Ave HR (%APMHR)	-	-.11	-.06	-.16	-.13	-.01	.32	1									
9	Ave Stepping Rate (per min)	-	-.39*	-.14	-.31	-.37*	.19	.78*	.41*	1								
Session Activity Level																		
10	Sedentary (%time)	-	.03	-.15	-.06	-.01	.30	-.61*	-.23	-.62*	1							
11	Light (%time)	-	.83*	.60*	.77*	.77*	.14	-.30	-.34	-.55*	-.07	1						
12	Moderate (%time)	-	-.51*	-.26	-.44*	-.49*	.18	.54*	.44*	.73*	-.66*	-.60*	1					
13	Vigorous (%time)	-	-.73*	-.50*	-.66*	-.68*	.04	.59*	.34	.77*	-.37*	-.81*	.64*	1				
14	Very Vigorous (%time)	-	-.39*	-.12	-.26	-.28	.14	.36*	.31	.55*	.12	-.50*	.22	.58*	1			
15	MVPA (%time)	-	-.67*	-.40*	-.59*	-.63*	.08	.63*	.46*	.84*	-.57*	-.78*	.91*	.90*	.49*	1		
Perceived Effort and Affect																		
16	sRPE (1-10)	-	.48*	.25	.42*	.47*	-.09	-.10	-.31	.30	.06	.45*	.33	-.41*	-.33	-.41*	1	
17	FS (-5 / +5)	-	.12	.21	.32	.35*	.34	.17	.06	.28	-.31	.11	.19	-.01	-.01	.11	.33	1

Note. sRPE = session Rating of Perceived Exertion; FS = Feeling State; * $p < .05$.

4. Benchmark Against other Forms of Physical Activity

We have used multiple methodologies to movement dynamics, physical activity intensity, self-reported exertion levels and overall enjoyment of playing a typical Hungerball session across 3 age groups. Importantly, the data presented in this report represent a sum of the whole experience including active game play as well as breaks between game-play. In considering all of the evidence collected, we conclude that Hungerball is a non-steady state moderate to vigorous intensity physical activity. Mean heart rates recorded across groups and games were approximately 75% of the age-predicted maximum value, which is considered consistent with "vigorous" activity intensity (Norton et al. 2010) and this is sufficient to provide an aerobic training stimulus to the cardiovascular system. Accelerometry-derived count values show that approximately 50% or more of the movements made during Hungerball are consistent with moderate to vigorous intensity (somewhat less in the Adult group). This data displays that high velocity; high amplitude movement is required to play Hungerball. Movement of this nature provides excellent stimuli for the development of motor control and motor literacy (Brockman et al. 2010 and Edwards et al. 2017).

With reference to the values reported in Tables 4 and 6, the various Hungerball games elicited an energy expenditure rate of approximately 3.4 METs (range 2.9 to 3.8 METs; note that this included time spent waiting to return to game play after being eliminated and break times between sessions). The average vertical axis accelerometry counts ranged between 1000 and 2200 counts (mean counts 1600). As previously mentioned, Reading and Prickett (2013) showed that MET values calculated from vertical axis accelerometry counts are reasonable but can underestimate non-steady state energy expenditure rates. Thus, the MET values reported here may underestimate the true energy expenditure rate of Hungerball play. Finally, the RPE values (4.2±2.5 out of 10) reported by the participants (Table 7) represent a moderate intensity activity (Norton et al. 2010). Rating of perceived exertion (RPE) scales can effectively quantify activity intensity; however, enjoyment of an activity can result in participants underestimating an activities true intensity (Leininger et al. 2010). This is especially possible given the high "positive" feelings scale measurement recorded for the Hungerball sessions (Table 7)

Table 9 (next page) provides representative activity intensity levels (METs) and accelerometer counts for various physical activities performed by children and adults that encompass sedentary/rest to moderate to vigorous intensity. The table values are derived from measurement of exhaled air to calculate the oxygen consumption rate and MET value (i.e., $1MET = 3.5mLO_2 \cdot kg^{-1} \cdot min^{-1}$) while simultaneously measuring movement using Actigraph GT3x accelerometers while the participant performed each different activity (Note: the same accelerometer make and model was used in this study). One thing that should be readily apparent in Table 9 is that it is very difficult to compare the activity intensities of different activities using accelerometry. For example, children riding a bike at $19km \cdot hr^{-1}$ have a measured MET value of 5.9 METs and 369 vertical axis accelerometer counts yet when compared to volleyball, there are 1433 vertical axis accelerometer counts and a measured MET value of 4.2METs. Similar disparities are present in adult data (Table 9). One cause of this disparity between measured MET value and accelerometry is the nature of the activity. Comparing different activities is a bit like comparing and apple to an orange no matter what methodology is used. For example, activities that occur more in 2-dimensional planes (e.g., jogging or running) tend to have higher accelerometry count values for a given MET value when compared to an activity that occurs in more movement planes in a non-steady state manner (e.g., basketball, volleyball, soccer).

Despite the limitations of accelerometry and being unable to directly measure exhaled air, we are able to show that Hungerball is a moderate to vigorous physical activity using combined methodology. Moderate to vigorous activities have energy expenditure rates extending from 3.0 to 9.0 METs (Norton et al. 2010). Based on this, Hungerball is comparable to activities such as those listed in Table 9 and the following activities listed in Haywood and Gibson 2014): **3.0METs** moderate weight lifting, Frizbee playing, surfing; **4.0METs** horseback riding, table tennis, bicycling 16km·hr^{-1}; **5.0METs** children's games such as hopscotch, dodgeball & tetherball, skateboarding, snorkelling; **6.0 METs** boxing a punching bag, hiking cross country, jogging, water skiing; **7.0METs** recreational soccer, tennis, racquetball; **8.0METs** competitive/beach volleyball, singles tennis, field hockey, basketball game; **9.0METs** orienteering, mountain/BMX bicycling, boxing-sparring.

Finally, with reference to the observed levels of perceived effort and negative/positive affect, it is interesting to note that whilst many forms of prescribed exercise (e.g., treadmill running) tend to show a negative correlation between perceived effort and positive affect (i.e., with higher levels of perceived effort being associated with more negative affect; Hardy & Rejeski, 1989), no sign of such a negative correlation appears to be observed in Hungerball (see Table 8). As such, Hungerball may enable individuals to exercise at moderate to vigorous levels of physical activity whilst ensuring that people enjoy themselves.

Table 9. MET values and accelerometry count values for various physical activities

Activity	METs	Accelerometer (vertical axis; counts·min^{-1})
Children (5 to16yrs)		
Lying down	1.3	0
Watch TV	1.0	2
Play computer video game	1.5	4
Throw and catch a ball	2.7	58
Volleyball	4.2	1433
Brisk walk (5.6kph)	4.8	3682
Bicycling (19.2kph)	5.9	369
Shooting basketball hoops	6.5	2002
Stair climbing (80 steps·min^{-1})	6.6	2138
Basketball game	7.2	3810
Soccer	7.4	4670
Run (8kph)	8.9	6330
Adults (30 to 50yrs)		
Lying down	1.0	4.8
Walking (4.8kph)	3.3	3600
Golf	4.3	2584
Walking (6.0kph)	4.4	5330
Racquetball	6.6	3575
Basketball	7.3	5570
Running (11kph)	9.4	9908

Note: Children's activity data from Trost et al. 2011, Treuth et al. (2004) and Romanzini et al. (2014) and are based on male and females aged 5 to 16yrs. Adult data based on Hendelman et al. (2000) and Crouter et al. (2006).

5. Conclusion

The evidence gained through the current study overwhelmingly supports the conclusion that Hungerball provides an enjoyable and engaging form of physical activity that can be enjoyed across a wide range of ages and physical literacy skill. Game play provides a moderate to vigorous cardiovascular training stimulus that would assist children and adults in meeting current physical activity guidelines in New Zealand. Furthermore, the multidimensional aspect of Hungerball game (i.e., activity equally divided across three motion planes) suggests that it may also provide a significant musculoskeletal training stimulus that would facilitate the development, refinement and maintenance of physical literacy. Finally, physical activity did not depend on prior experience or skill and gameplay was consistently associated with strong positive affect. Thus, it is concluded that Hungerball provides a fun and enjoyable exercise that – if played on a regular basis – should positively contribute to health and physical literacy from childhood through to adulthood.

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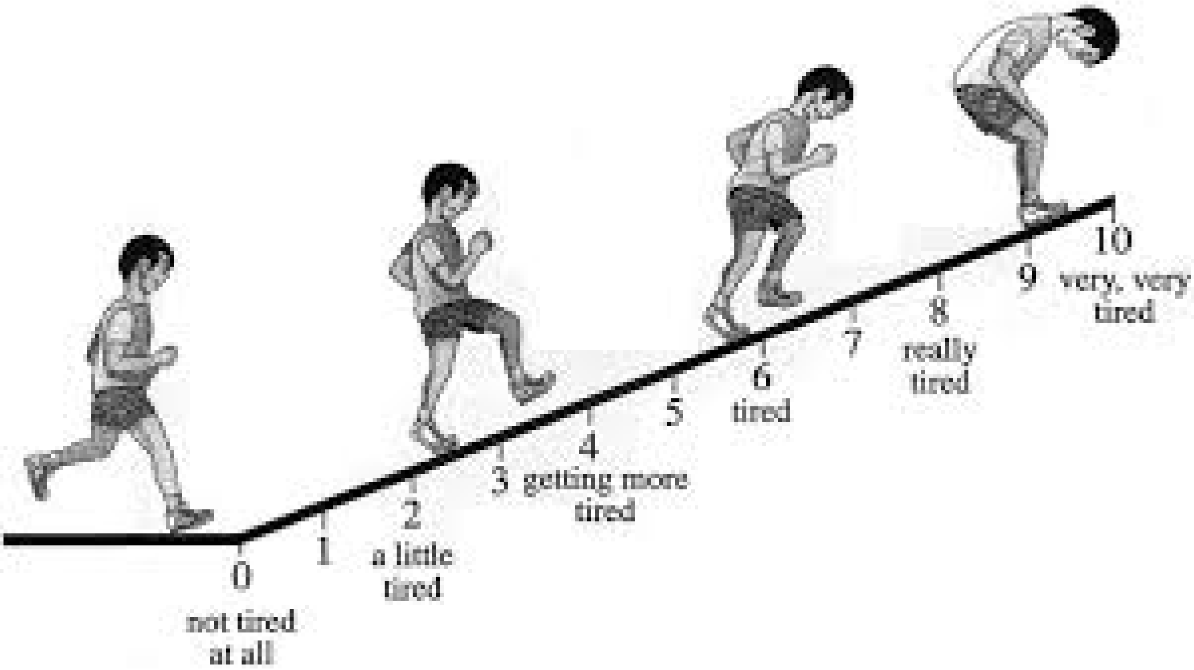
7. Appendices

(Appendix 1) OMNI Perceived Exertion Scale.



Appendix 2. Feeling Scale.

While participating in exercise it is quite common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasurable.

How did you feel during the past Hungerball session?

	**+5**	**Very Good**
	+4	
	+3	**Good**
	+2	
	+1	**Fairly Good**
	**0**	**Neutral**
	-1	**Fairly Bad**
	-2	
	-3	**Bad**
	-4	
	**-5**	**Very Bad**