Original Paper

Understanding Youth’s Ability to Interpret 3D Printed Physical Activity Data and Identify Associated Intensity Levels

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Abstract

**Background:** A significant proportion of youth in the UK fail to meet the recommended 60 minutes of moderate-to-vigorous physical activity (MVPA) every day. One of the major barriers encountered in achieving these physical activity recommendations is the perceived difficulty for youths to interpret physical activity intensity levels and apply them to everyday activities. Advances in 3D printing have enabled novel ways of representing physical activity levels through personalised tangible 3D models.

**Objective:** The purpose of this research was to elicit youths (children and adolescents) interpretations of two age-specific 3D models displaying PA, and to assess their ability to appropriately align activities to the respective intensity.

**Methods:** Twelve primary school children (9 boys; 7.8 ± 0.4 years) and 12 secondary school adolescents (6 boys; 14.1 ± 0.3 years) participated in individual semi-structured interviews. Interview questions, in combination with two interactive tasks, focussed on youths’ ability to correctly identify PA intensities and interpret an age-specific 3D model. Interviews were transcribed verbatim, content analysed, and outcomes represented via tables and diagrammatic pen profiles.

**Results:** Youths, irrespective of age, demonstrated a poor ability to define moderate-intensity activities. Moreover, children and adolescents demonstrated difficulty in correctly identifying light- and vigorous-intensity activities, respectively. Whilst youths were able to correctly interpret different components of the age-specific 3D models, children struggled to differentiate PA intensities represented on the models.

**Conclusion:** These findings support the potential use of age-specific 3D models of PA to enhance youths’ understanding of the recommended guidelines and associated intensities.

Introduction

Regular physical activity is considered an essential part of youths’ overall physiological health and psycho-social development [1-4], preventing adverse health risks, such as early-onset cardiovascular disease, obesity and type 2 diabetes [5-7]. The World Health Organisation (WHO) and UK Government both recommend that youths (children and adolescents) aged 5 to 17 years should engage in at least 60 minutes moderate-to-vigorous physical activity (MVPA) every day [8, 9]. Despite this, reports show that only 21% of boys and 16% of girls in the UK meet these current physical activity recommendations [10, 11]. One of the major barriers to achieving these physical activity recommendations is youths’ lack of knowledge of these targets and limited ability to interpret the associated intensities [12-14], and therefore an inability to apply the terms to their everyday activities.
A crucial step in designing a successful physical activity promotion intervention is that of understanding the factors that affect the type, frequency, duration and intensity of youths’ physical activity [15]. Indeed, previous research has explored youths’ understanding and perceptions of physical activity duration, frequency and intensities, finding they had a limited ability to classify intensity levels [16-19]. Furthermore, youths’ inability to define and understand the intensity of physical activity may, in part, explain the inconsistent reliability and validity of children’s self-reported physical activity levels [20-22]. Whilst there is currently a paucity of literature on youths’ perceptions of physical activity intensity, it is evident that the development of personal feedback tools [23] which seek to enhance their understanding of the importance of physical activity, and indeed interpret the recommended guidelines, are warranted.

Digital mediums, such as activity tracking tools and smartphone devices with assisted apps, have allowed greater accessibility for users to visualise their personal physical activity data. Visualisations are known for enabling users to understand their personal data and associations with physical activity levels, making them more comprehensible and actionable in terms of health-related aims [24]. However, on-screen visualisations are limited to visual stimulation and ignore the abundance of other senses, such as ‘touch’, that could potentially enrich personal engagement with data [24, 25]. This is especially pertinent to the current population, with 80% of youths visual and tactile learners [26]. With recent developments in 3D printing, Khot et al. [27] investigated the use of an innovative visualisation strategy involving 3D printing to create tangible physical activity data for adults, demonstrating that the visual and tactile nature of the data increased the user’s awareness and reflection of their personal physical activity behaviours. Indeed, tangible interfaces have been shown to increase engagement and reflection in youths’ role in active learning [28]. More recently, formative research on youths demonstrated their ability to conceptualise 3D-printed objects of physical activity, highlighting a preference for 3D models, represented through abstract and graphical designs, to potentially facilitate their understanding, awareness and motivation to engage in more physical activity [14]. Indeed, such research led to the development of two age-specific 3D-printed model prototypes. However, it is presently unclear whether youths can correctly interpret the different models in terms of the amount and intensity of daily physical activity. Based on the technology design framework developed by Druin et al [29], the present study implements the role of the tester, whereby children are the testers of the new technology and their experiences can be observed and evaluated for impact by researchers.
The aims of this study were, therefore, to (i) examine children and adolescents’ perceptions and ability to identify physical activity intensities (i.e., sedentary, light, moderate and vigorous); (ii) elicit children and adolescents’ interpretations of the age-specific 3D model prototypes, and; (iii) use the data to consolidate the design of the age-specific 3D model prototypes to inform the development of a school-based physical activity intervention.

Methods

Recruitment

Participants were a convenience sample taken from two primary schools and two secondary schools in South Wales, UK. In total, twelve primary school children (9 boys; 7.8 ± 0.4 years) and 12 secondary school adolescents (6 boys; 14.1 ± 0.3 years) participated in the study. Parents and youths returned informed written consent and assent prior to participation, respectively. All procedures were approved by the University Ethics Committee and were conducted in accordance with the Declaration of Helsinki (ref: PG/2014/40).

Procedures

Twenty-four semi-structured individual interviews were conducted with youths by the first author, either within a familiar classroom or the school library [30]. Individual interviews are supported as a suitable method for exploratory research seeking to generate diverse and original ideas within youths [31]. Interview questions were adjusted for tone and structure to ensure age-appropriateness; all interview questions and tasks were reviewed, discussed and revised by authors SGMC, MAM, ZRK and KAM. The interview questions (see examples in Table 1) were informed by previous formative research [14] and addressed concepts such as youths’ knowledge of physical activity intensities and youths’ interpretations of the age-specific 3D models (Figure 1A & 1B). Complementary to the interview questions, youths were asked to complete two interactive tasks: i) a physical activity and intensity-matching task, and; ii) a 3D-model recall and interpretation task. The first task was completed at the mid-point of the interview process and invited participants to match twenty different pictures of activities (e.g., video gaming, walking, climbing stairs, football) to the correct intensity (i.e., sedentary, light, moderate and vigorous; Table 2). Sedentary activities were based on Trost et al. [32], with light, moderate and vigorous activities obtained from the youth compendium of physical activities [33, 34]. After completion of the task, participants were asked to describe why they placed each activity within the specific intensity box.
<table>
<thead>
<tr>
<th>Interview</th>
<th>Topic</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children/Adolescents</td>
<td>Physical Activity Intensity</td>
<td>Can you tell me what you think these different levels of intensity for physical activity might be?</td>
</tr>
<tr>
<td>Children/Adolescents</td>
<td>Physical Activity Intensity</td>
<td>What word would you use to describe the intensity of that activity [e.g., climbing stairs]?</td>
</tr>
<tr>
<td>Children/Adolescents</td>
<td>Physical Activity Model</td>
<td>What do you think the lines/bars show?</td>
</tr>
<tr>
<td>Children/Adolescents</td>
<td>Physical Activity Model</td>
<td>Can you tell me what you think the rest of the physical activity model shows? (Prompt: how do you think this model (sun or bar chart) shows physical activity?)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>Eating, sitting</td>
</tr>
<tr>
<td></td>
<td>Reading, lying down</td>
</tr>
<tr>
<td></td>
<td>Mobile phone, sitting</td>
</tr>
<tr>
<td></td>
<td>Computer, sitting</td>
</tr>
<tr>
<td></td>
<td>Video games, sitting</td>
</tr>
<tr>
<td>Light (&lt;3.0 METs)</td>
<td>Fishing, sitting</td>
</tr>
<tr>
<td></td>
<td>Stretching exercises</td>
</tr>
<tr>
<td></td>
<td>Darts, wall</td>
</tr>
<tr>
<td></td>
<td>Walking, slow</td>
</tr>
<tr>
<td>Moderate (3.0 – 6.0 METs)</td>
<td>Throwing, snowball</td>
</tr>
<tr>
<td></td>
<td>Sweeping</td>
</tr>
<tr>
<td></td>
<td>Mowing lawn</td>
</tr>
<tr>
<td></td>
<td>Climbing stairs</td>
</tr>
<tr>
<td>Vigorous (&gt;6.0 METs)</td>
<td>Climbing trees</td>
</tr>
<tr>
<td></td>
<td>Football/soccer</td>
</tr>
<tr>
<td></td>
<td>Tennis</td>
</tr>
<tr>
<td></td>
<td>Hockey, field</td>
</tr>
<tr>
<td></td>
<td>Running, hard effort</td>
</tr>
<tr>
<td></td>
<td>Swimming laps</td>
</tr>
<tr>
<td></td>
<td>Riding a bicycle, hard effort</td>
</tr>
</tbody>
</table>

The second task was completed at the end of the interview to test youths’ ability to recall and interpret the different components of the age-specific 3D models. The formatively-developed 3D models were designed by children, who displayed a preference for a sun (Figure 1A) and adolescents (bar chart; Figure 1B), using Play-Doh™ as a prototype tool for creation [14]. Both models depict moderate and vigorous physical activity levels achieved for each day, across a week, as well as a reference bar to the physical activity guidelines of 60 minutes MVPA. All participants were asked to label a 2D diagram of the relevant model and to verbally describe the model’s components.

[Insert Figure 1.]

Figure 1. 3D model prototypes; 1A = Children’s Sun 3D Model, 1B = Adolescents’ Bar Chart 3D Model; PA = Physical Activity, MVPA = Moderate to Vigorous Physical Activity
Interviews lasted 35.8 ± 5.3 and 25.1 ± 4.9 minutes for children and adolescents, respectively. All the interviews were digitally voice (Olympus DM-520 digital voice recorder, Shinjuku, Japan) and video (Sony Handycam HDR-PJ540, Minato, Japan) recorded and transcribed verbatim. In total, 85 and 92 pages of raw transcription data, Arial font, size 12, double-spaced were produced for primary school children and secondary school adolescents, respectively. Unique identification codes were used to ensure anonymity of participants within all transcripts: B (boy) or G (girl), followed by participant number.

Data analysis

Transcripts were thematically analysed by the first author (SGMC) using three steps: data immersion, coding and identifying themes [35]. The immersion of the data was completed in an active way of ‘repeated reading’ of the transcripts, searching and noting of meanings and patterns within the data set [35]. The process of coding, using a manual cut and paste technique, organised the data into meaningful groups that were considered pertinent to the research questions [35]. Key themes were identified by collating the relevant coded data quotes and discarding any irrelevant quotes from the analysis [35]. A frequency count of the compiled meaningful quotes was conducted to record the number of participants that noted respective points within a theme. The meaningful quotes and frequency counts were then presented diagrammatically using a pen profile approach, which is considered an appropriate method for representing diagrams of key emergent themes [36]. The last author (KAM) independently analysed the data and discussed the outcomes with SGMC. Through the repeated process of reverse triangulation, author MAM critically cross-examined the data in reverse from the pen profiles to the transcripts until all alternative interpretations of the data were exhausted. The pen profiles were then assessed by all other authors, enabling further interpretations and adjustments prior to a final consensus was reached. For the activity intensity-matching task, the activities placed into certain key intensity boxes were counted (sedentary, light, moderate and vigorous) and aligned with direct quotations (Table 3).

Statistics

A “N – 1” Chi-squared test was conducted using IBM SPSS Statistics 22 (Chicago, IL) to determine any significant differences between boys and girls who correctly associated activities to their respective intensity, with statistical differences accepted at \( p \leq 0.05 \) [37, 38].
Results

Youths’ understanding of physical activity intensities are presented in Table 3 (children) and Table 4 (adolescents), with representative verbal statements for each activity reflecting the youths’ greatest intensity level frequency count.

Children’s Ability to Identify Physical Activity Intensities

Children were able to correctly align sedentary-based activities with the respective intensity 62% of the time, with girls demonstrating a better understanding of sedentary behaviour than boys (girls 80% vs. boys 53%; $P = 0.38$). Specifically, the sedentary activities most commonly correctly-identified were technology-based behaviours, such as playing on a mobile phone (75%) or computer (75%), and video gaming (75%). A number of children (58%) reported that eating was a light-intensity as “eating’s easy cause you’re just like moving your arms and putting it [food] in your mouth” (PB06). Children were only able to correctly identify light-intensity activities 31% of the time, with girls showing a better understanding of light-intensity activities than boys (girls 38% vs. boys 28%; $p > 0.05$). A number of children (75%) indicated stretching as a moderate-intensity activity because “for some people stretching is really hard…” (PB06), with one child associating stretching with “when I do rugby you have to warm up and that’s not hard, easy or inactive” (PB07). Furthermore, fishing was identified by five children as a sedentary behaviour due to the nature of the sitting position, stating “he’s just sitting down and waiting for a fish…” (PG11). Similarly, some children struggled to define moderate-intensity activities, with only 33% of moderate activities being correctly identified. Boys, as a group, fared somewhat better in allocating moderate-intensity activities in comparison to girls (boys 38% vs. girls 25%; $P = 0.66$). Children perceived moderate activities, such as throwing (83%), climbing stairs (75%) and sweeping (58%) as light-intensity activities. Specifically, climbing stairs was thought of as a light-intensity activity because “all you’ve got to do is lift a foot and put it on each step” (PB09), with sweeping being noted as something that “you can relax while you’re doing it [sweeping]” (PB02). Vigorous activities were correctly identified 68% of the time by children (boys 73% vs. girls 57%; $P = 0.58$). Vigorous-intensity activities, such as riding a bicycle (92%), hockey (92%), tennis (67%), swimming laps (58%), football (58%), running (50%) and climbing trees (50%), were all correctly classified. Children described the nature of vigorous-intensity as riding a bicycle or running making “you…really tired” (PB09) or “you get a little tired…” (PB01), respectively. When referring to swimming laps there was an emphasis on “my swimming teacher pushes me really hard” (PB07).
Adolescents’ Ability to Identify Physical Activity Intensities

Adolescents correctly identified sedentary-based activities 87% of the time, with boys demonstrating a better understanding when compared to girls (boys 90% vs. girls 83%; \( P = 0.73 \)). Sedentary technology-based activities, such as playing on a mobile phone (100%) or computer (92%), and video gaming (75%), were all correctly perceived as sedentary behaviours; for example: “they’re just on their electronics, playing games or watching something...they don’t really have to put effort into that and they’re not moving around or doing anything” (SB01).

Light-intensity activities were correctly placed 71% of the time, with girls displaying a better understanding than boys (girls 75% vs. boys 67%; \( P = 0.77 \)). Light-intensity activities, walking (83%), fishing (67%), darts (67%) and stretching (67%), were all consistently identified as being a light-intensity activity. Adolescents correctly identified moderate-intensity activities only 10% of the time (girls 13% vs. boys 8%; \( P = 0.07 \)). All adolescents reported that the activity of throwing (100%) was a light-intensity activity. Other moderate activities, such as mowing the lawn (75%), climbing stairs (75%) and sweeping (67%), were also classified as light-intensity, expressing them as “everyday things like mowing the lawn” (SG09). Adolescents’ were only able to appropriately identify vigorous-intensity activities 46% of the time, with girls demonstrating a greater ability to recognise vigorous-intensity activities than the boys (girls 62% vs. boys 24%; \( P = 0.20 \)). Adolescents correctly categorized individual fitness activities, such as cycling (75%), running (67%) and swimming (50%) as vigorous-intensity activities. In contrast, organised sport activities, such as football (75%), tennis (67%) and hockey (58%), were often identified as moderate-intensity, even though they regarded football and tennis as “…quite a physical sport” (SB03) or involving “…strengths” (SB04), respectively.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Activity Item</th>
<th>Representative Verbal Statement</th>
<th>SED</th>
<th>LPA</th>
<th>MPA</th>
<th>VPA</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>Eating, sitting</td>
<td>“Eating’s easy cause you’re just like moving your arms and putting it [food] in your mouth” PB06</td>
<td>5</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>62%</td>
</tr>
<tr>
<td>Sedentary</td>
<td>Reading, lying down</td>
<td>“That one cause you’re just lying there” PB03</td>
<td>5’</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>62%</td>
</tr>
<tr>
<td>Sedentary</td>
<td>Mobile phone, sitting</td>
<td>“These [mobile phone use] are quite easy cause all you’re doing is basically moving your fingers” PB02</td>
<td>9’</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>62%</td>
</tr>
<tr>
<td>Sedentary</td>
<td>Computer, sitting</td>
<td>“Computer you just sitting down and probably typing something with mouse and this you’re just going [acts out typing]...” PB07</td>
<td>9’</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>62%</td>
</tr>
<tr>
<td>Sedentary</td>
<td>Video games, sitting</td>
<td>“They are like playing video games, this is inactive because you’re not actually like moving” PB06</td>
<td>9’</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>62%</td>
</tr>
<tr>
<td>Light</td>
<td>Fishing, sitting</td>
<td>“He’s just sitting down and waiting for a fish but when he winds it in he’s using kind of his muscles” PG11</td>
<td>5’</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>31%</td>
</tr>
<tr>
<td>Light</td>
<td>Stretching exercises</td>
<td>“Cause when i do rugby you have to warm up and that’s not hard, easy or inactive” PB07</td>
<td>0</td>
<td>2</td>
<td>9’</td>
<td>1</td>
<td>31%</td>
</tr>
<tr>
<td>Light</td>
<td>Darts, wall</td>
<td>“Throwing darts is pretty easy but not to hit the middle [of the dart board]” PB02</td>
<td>0</td>
<td>9’</td>
<td>4</td>
<td>3</td>
<td>31%</td>
</tr>
<tr>
<td>Light</td>
<td>Walking, slow</td>
<td>“Walking to school’s easy, all you’re doing is like moving your legs” PB06</td>
<td>1</td>
<td>7’</td>
<td>3</td>
<td>1</td>
<td>31%</td>
</tr>
<tr>
<td>Moderate</td>
<td>Throwing, snowball</td>
<td>“Throwing snowballs is quite easy because you can just throw them any way you like” PB02</td>
<td>0</td>
<td>10’</td>
<td>2</td>
<td>0</td>
<td>33%</td>
</tr>
<tr>
<td>Moderate</td>
<td>Climbing stairs</td>
<td>“I’ve put walking up steps because quite easy because all you’ve got to do is lift a foot and put it on each step” PB09</td>
<td>0</td>
<td>9’</td>
<td>3</td>
<td>0</td>
<td>33%</td>
</tr>
<tr>
<td>Moderate</td>
<td>Sweeping</td>
<td>“And sweeping because you can relax while you’re doing it” PB02</td>
<td>0</td>
<td>7’</td>
<td>5</td>
<td>0</td>
<td>33%</td>
</tr>
</tbody>
</table>
Vigorous

Intensity

Vigorous

Light

represents representative verbal statement frequency count, '*' denotes significant difference between gender intensity identification (activity, VPA = Vigorous physical activity. '%' denotes percentage of participants correctly aligning to intensity level, "Figure legend S = Secondary, B = Boy, G = Girl, n = frequency count,SED = Sedentary, LPA = Light physical activity, MPA = Moderate physical activity, VPA = Vigorous physical activity. ‘%’ denotes percentage of participants correctly aligning to intensity level, “#” denotes the representative verbal statement frequency count, “**” denotes significant difference between gender intensity identification (p < 0.05).

Table 4 Adolescents’ ability to identify activities to intensity

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Activity item</th>
<th>Intensity Level Frequency Count (n)</th>
<th>Representative Verbal Statement</th>
<th>SED</th>
<th>LPA</th>
<th>MPA</th>
<th>VPA</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>Eating, sitting</td>
<td>“Eating, maybe just a little bit of movement when you’re like bringing it [the food] up to your mouth and then when you’re chewing” SB02</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reading, lying down</td>
<td>“Reading a book all you’re doing is just flipping a page with almost nothing movement...” SB02</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile phone, sitting</td>
<td>“They’re just on their electronics...they don’t really have to put effort into that and they’re not moving around or doing anything” SG01</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>87% B = 90% G = 83%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Computer, sitting</td>
<td>“Yeah well obviously computer games...you’re not doing much except moving your fingers maybe” SB03</td>
<td>11</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Video games, sitting</td>
<td>“Playing games...like some things that don’t require that much movement” SG10</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>Fishing, sitting</td>
<td>“Fishing you’re just waiting in a boat and when a fish comes you have to reel it...” SB02</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stretching exercises</td>
<td>“It’s [stretching] not like big movement like they’re not really doing much” SB11</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Darts, wall</td>
<td>“Darts, all you’re doing is just throwing a small dart at a small target” SB02</td>
<td>3</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>71% B = 67% G = 75%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walking, slow</td>
<td>“...walking to school you do need to walk obviously but it’s not very hard...” SB02</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Throwing, snowball</td>
<td>“Throwing a snowball not much at all, all you have to do is just craft this little ball of precipitation and throw it at someone else” SB02</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Climbing stairs</td>
<td>“Like walking up the stairs, it’s sort of easy...you can get a bit out of breath” SB04</td>
<td>0</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>10% B = 8% G = 13%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sweeping</td>
<td>“They’re just like doing something simple, like their daily life” SG05</td>
<td>4</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mowing lawn</td>
<td>“Light is mostly just...everyday things like mowing the lawn” SG09</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vigorous</td>
<td>Climbing trees</td>
<td>“Climbing a tree cause it does take a lot of effort to climb a tree” SG01</td>
<td>0</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tennis</td>
<td>“Just some like basic sports...people would think they’re fairly easy...running, football and tennis” SG10</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swimming laps</td>
<td>“Swimming...you have to be able to do the right streamlined technique to be able to glide through the water and then...you need to be able to breathe...” SB02</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>43% B =24%, G = 62%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hockey, field</td>
<td>“A girl playing hockey you need to run around the pitch many times and it might get a bit tiring” SB02</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Football/Soccer</td>
<td>“I put quite a few in medium because like football is quite a physical sport” SB03</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Running, hard effort</td>
<td>“These are probably the ones like make you push yourself” SB11</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Riding a bicycle, hard effort</td>
<td>“Like cycling when you’re going up hills and stuff, it depends like how strong you are...” SB04</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3D Model Understanding

Children and adolescents’ interpretations of the age-specific 3D models are presented in two separate pen profiles (Figures 2 and 3, respectively).

Children’s Understanding and Ability to Interpret the 3D Model

In total, six higher order themes were structured around the 3D model’s components: ‘Physical Activity Guideline Bar’, ‘Daily Physical Activity Bars’, ‘Moderate Physical Activity Bar’, ‘Vigorous Physical Activity Bar’ and ‘Separator of MVPA Bar’ (Figure 2). A number of children (75%) were able to interpret the physical activity guideline bar on the 3D model as “the 60-minute time bar” (PG10). All children correctly identified that the 3D model represented a week of physical activity “Monday they did a lot [of physical activity], on Tuesday they did a tiny bit, on Wednesday they did a tiny bit less…” (PG05). The data revealed that 58% of children had some difficulty interpreting the moderate physical activity bar on the 3D model, with children expressing the bar as “…the easy activity to be doing because you do easy more than hard…” (PB01). Only 42% of children were able to correctly interpret the moderate physical activity bar as the “Medium activity…” (PG05). Ten children (83%) correctly interpreted the vigorous physical activity bar as “how much you’ve done of the hard level [of physical activity]” (PG11), with only two children incorrectly interpreting the bar as the time at which the physical activity was undertaken “the morning [of physical activity] and that might be the afternoon [of physical activity]”. The circle separator along the Sun rays splitting the moderate and vigorous physical activity bars was correctly interpreted by 67% of children as “the blob splits the line up, so you know how many of the hard [physical activity] and how many of the medium [physical activity]” (PG11). Only two children expressed that they did not understand the meaning of the moderate-to-vigorous separator along the ray.

[Insert Figure 2.]

Figure 2. Children’s interpretation of sun 3D model. Figure legend P = Primary, B = Boy, G = Girl, PA = Physical Activity, N = frequency counts.

Adolescents’ Understanding and Ability to Interpret the 3D Model

Five higher order themes were identified around the 3D model components: ‘Physical Activity Guideline Bar’, ‘Daily Physical Activity Bars’, ‘Moderate Physical Activity Bar’ and ‘Vigorous Physical Activity Bar’ (Figure 3). The physical activity guideline bar was correctly interpreted by 83% of adolescents as “that’s the amount [of physical activity] you need to be doing or more…sixty minutes a day” (SP12), with only two participants unable to identify the meaning of the target bar. All of the adolescents had a good understanding of the physical activity data.
being represented as a week, with 42% of those adolescents able to interpret the data without any previous explanation or guidance from the facilitator. The moderate-intensity physical activity bar was correctly reported by 75% of adolescents as “…the moderate activity that you [themselves] were doing” (SG01), with only three participants incorrectly defining it as “how much sport you [themselves] have done” (SG6). All adolescents demonstrated a good understanding of the vigorous-intensity physical activity bar, stating “…this means how much hard activity you [themselves] are doing…” (SB03).

Figure 3. Adolescents’ interpretations of bar chart 3D model. Figure legend S = Secondary, B = Boy, G = Girl, PA = Physical Activity N = frequency counts.

Discussion

The aims of this study were to ascertain youths’ understanding of the age-specific 3D model designs and to examine youths’ perceptions and ability to identify activities according to their respective intensity. The present study findings suggest that youths demonstrate misconceptions in defining different activity intensities. However, youths’ ability to interpret the age-specific 3D models supports the use of these formatively-designed tangible representations of physical activity within an intervention to aid youths understanding and awareness of the recommended 60 minutes MVPA [14].

To date, little research has explored how youths understand the meaning of the term physical activity [19, 32, 39, 40]. It has previously been suggested that the terminology developed by adults used to describe physical activity is too complicated for youths, due to developmental and vocabulary differences [19]. As highlighted by Pearce et al. [19], understanding how children express physical activity is a logical first step for improving overall knowledge and the development of innovative methods for enhancing physical activity. In the present study, the intensity-matching task revealed that adolescents have a greater ability to identify sedentary behaviours and light-intensity activities, whilst children showed they could more accurately identify the two extremes of intensity (i.e., sedentary behaviours and vigorous-intensity activities). It could be expected that as a result of children’s sporadic and explosive patterns of activity [3, 41-44], moving from one extreme intensity to another, could explain, in part, the present findings demonstrating children’s limited ability to identify the intermediary light and moderate-intensity activities. Furthermore, the present study showed that only 25% of children thought that working on the computer was a physical activity, with no children characterizing ‘sweeping’ as a sedentary behaviour when compared to Trost et al.’s [32] findings of 38% and 30%, respectively. Whilst Trost et al [32]. encompassed a larger sample of 9-10
year olds, such discrepancies may be due, at least in part, to the reduced sample size and wider age range in the present study. Conversely, it could be argued that the timeframe in which the research was implemented could play an influencing role on youths’ understandings of physical activity. For example, since the mid-2000s, the number of campaigns with mass media components have led to an increased level of exposure to the importance of physical activity behaviours within youths, with evidence supporting this exposure-response relationship [45-47].

The majority of children tended to over-estimate light-intensity activities, such as stretching exercises, darts and fishing. In some cases, children would associate stretching exercises with other more demanding activities, such as “…when I do rugby you have to warm-up…” (PB07). This type of category contamination was a recurring theme within children, with other activities, such as throwing (light) and climbing trees (vigorous) being associated with “…running around…” (PB01). In most cases, this category contamination led to an increase in intensity of the dominating activity (i.e., going from light- to moderate-intensity). Furthermore, light-intensity activities, such as darts and fishing, were often inaccurately identified because of the perceived skill or competence required to complete the activity. Specifically, playing darts was considered a vigorous-intensity activity as it required a certain skill to “…get it [the dart] in the middle [of the dart board]” (PG05), with fishing associated with moderate-intensity because it’s “…quite hard to catch fish” (PB02). Skill-level was identified as a common characteristic for other activities, including football, hockey, swimming, riding a bicycle and climbing trees, with one child stating reading as a vigorous-intensity because “…you have to learn how to read words” (PB06). Consistent with previous findings [19], this study emphasises that skill in an activity, or physical competence, influenced children’s perceptions of the intensity level. It could be speculated that children’s perspectives of these skill- or physical competence-associated activities, are likely to undergo change and refinement as a consequence of time with personal experience and maturation [39]. However, this perspective appears unconvincing, as evidence suggests that adults also have a lack of knowledge when it comes to determining intensities of physical activity [13]. Therefore, this demonstrated inability to define intensities further highlights the importance of educating youths about different intensities of physical activity, so that as they age, their understanding of physical activity is more likely to reflect the actual intensity according to those associated with the recommended guidelines.

It is important that youths understand the type of physical activities that form moderate- and vigorous-intensity levels to increase the chances of youths’ engaging with these type of activities and to gain the associated metabolic health benefits [48-50]. In the present study, youths demonstrated a limited ability to correctly identify moderate-intensity activities, although the degree of this inaccuracy was much greater in adolescents. It could be postulated
that youths inability to identify moderate-intensity activities could be aligned to their limited capacity to describe how a physical activity could be performed at different intensities or effort levels [33]. However, youths underestimated the intensity levels of moderate activities related to either household chores, such as sweeping and mowing the lawn, or the daily activity of climbing stairs. Adolescents described such moderate activities as “…everyday things like mowing the lawn” (SG09) and “…like it’s easy” (SB04), with children suggesting, when climbing stairs that “…all you’ve got to do is lift a foot and put it on each step” (PB09). These findings support those of Trost et al. [32], as household chores and climbing stairs are not considered as important contributory sources of physical activity, with the present study further highlighting that this under-estimation increased with age. Nonetheless, it is perhaps pertinent to consider the applicability of some activities, such as household chores, as a lack of familiarity may have led to exaggerated inaccuracies with respect to the intensity of these activities [51]. For adolescents, the more commonly-performed individual sports (swimming, running and cycling) were correctly identified as vigorous-intensity, with team sports such as football, hockey and tennis perceived to be of a moderate-intensity. Indeed, evidence suggests that the more the activity is considered as play or fun, the less likely youths are aware of the intensity [19]. Although there is limited evidence of this within the present findings, it could be speculated that the greater level of social interaction during team sports [52] and the perceived conception of these team activities being for play or fun, could function as a moderator to youths’ ability to correctly assess the respective intensity [19]. The present findings highlight the need to further understand how context (i.e., social settings) mediates youths’ ability to interpret intensities between team sports and the more individual pursuit sports. Additionally, research is warranted to investigate the potential differences between non-athletic youths and sports orientated youths’ understanding and ability to conceptualise intensities.

Inconsistencies in youths’ ability to correctly identify and understand different activity intensities observed in this study are important, especially given that children’s self-report physical activity questionnaires rely on youths’ ability to correctly interpret activities in accordance to the intensity level [19]. The reliability and validity of data derived from measuring youth’s physical activity using self-report questionnaires is problematic [20-22]. From the present findings, it could be postulated that the inconsistent reliability and validity of physical activity questionnaires is, at least in part, youths’ misinterpretations and lack of understanding of intensity, supporting the findings of LeBlanc and Janssen [53]. Indeed, the findings support the idea that youths are not accustomed to relating their physical activity by intensity as a result of limited understanding, and therefore, this makes it challenging to conduct interventions aimed at changing intensities of physical activity.
One method that has the potential to develop youths’ comprehension of physical activity levels and associated activity intensities is the use of tangible interfaces (i.e., 3D models) to aid learning [54]. A large proportion of youths (79%) could correctly identify and describe the current physical activity guidelines projected on the 3D models. Youths’ ability to understand the physical activity guideline as a tangible representation will offer a more haptic and proprioceptive experience than visual representations alone [55], which is especially pertinent given that 80% of youths’ are visual and tactile learners [26]. It is anticipated that the 3D models will act as a form of concept map, whereby youths can make connections, relationships and understand that the concepts about physical activity are not just factual, but ideas to increase comprehension and expand vocabulary [56]. Previous research has suggested that physical materials can promote learning and might offer a more natural interaction than other types of learning interfaces (i.e., digital) [57-59]. Indeed, research has suggested that tangible interfaces play an important role in engaging youth in playful learning [60]. The present findings support this research, with youths demonstrating a good ability to interpret and understand the age-specific 3D models. Although, adolescents demonstrated a greater understanding of the age-specific 3D models and the different representations of physical intensities when compared to children, which could be explained by the Piagetian developmental theory [61]. Evidence suggests that the exploratory nature of learning through tangible interfaces, such as 3D models of physical activity, may offer a more supportive solution to enhancing children’s understanding in identifying patterns (i.e., between activities and intensities), and new concepts about physical activity than previous digital methods [54].

Limitations

Whilst data saturation was reached and lends further credibility to the present findings, the study is limited by the relatively small sample size, age range and the geographical area of data collection, which may under-represent other social-economic groups and ethnic minorities. Therefore, the present findings on youths’ understanding of the age-specific 3D models and demonstrated ability to identify activities to respective physical intensities should not be generalised but considered as a stimulus for future investigation.

Conclusion

This study shows that both children and adolescents have misconceptions when identifying corresponding activity intensities. Specifically, children showed recurring intensity classification errors, such as category contamination and perceived skill or competence of an activity leading to misperceptions of intensity, with both age groups severely underestimating moderate-intensity activities. However, youths demonstrated a good ability to interpret and describe the age-specific 3D model representations of physical activity, intensity and the recommended guideline.
Therefore, this study highlights the potential utility of these age-specific 3D printed models within an intervention to act as an educational tool to enhance youths understanding and awareness of the recommended physical activity guidelines and associated intensities.

Acknowledgments

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Conflicts of Interest

None declared

Abbreviations

B Boy
P Primary
G Girl
LPA Light physical activity
MPA Moderate physical activity
MVPA Moderate-to-vigorous physical activity
PA Physical activity
SED Sedentary
S Secondary
VPA Vigorous physical activity
WHO World Health Organisation

References


51. Li, S. ‘It’s all about me, me, me!’ Why children are spending less time doing household chores. Education, 2016.