Validation of the CSA Accelerometer in Adolescent Boys During Basketball Practice

Dawn Coe and James M. Pivarnik

Junior high school male basketball players \( n = 10 \) were assessed during a 55-min practice to evaluate the validity of the Computer Science and Applications, Inc. (CSA) accelerometer for estimating physical activity (PA). Direct observation (Five-Level Children’s Activity Rating Scale [CARS]) and heart rate monitoring (HR) were used as criterion measures. CSA, CARS, and HR values were recorded during each minute of practice. Correlation using group data showed a moderate to good \( r = 0.60; P < .001 \) relationship between CSA and HR. Individual participant analyses revealed a significant correlation (range 0.54–0.81; \( P < .001 \)) between CSA and HR in nine of ten subjects. ANOVA revealed significant differences \( P < .001 \) in CSA and HR in values associated with CARS levels 2–4. The CSA provides valid estimates of PA intensity (compared to CARS and HR) during basketball played by adolescent boys. It appears that CSA is sufficiently sensitive to quantify physical activity level as well as to discriminate between various intensity levels that exist during a typical basketball practice session.

Introduction

Physical activity (PA) is an essential component of a healthy lifestyle. Researchers assess PA to determine both the amount and intensity of activity being performed. Accelerometry has become one of the most widely used methods of assessing PA in large population studies (15).

The Computer Science and Applications, Inc. accelerometer (CSA) is a motion-sensitive device that researchers use to evaluate PA in a quantitative fashion (8, 9, 14, 15, 16). The CSA is unobtrusive and comfortable for the children to wear. The CSA has no external buttons so there is minimal chance of data loss due to subject tampering. The CSA is able to record for several days and can be programmed to begin and end data collection at specific times. Stored data can be downloaded easily via a personal computer (PC).

The CSA has been validated as a PA monitor in laboratory settings, using standard activities such as treadmill walking or running at specific speeds and grades. The criterion measure used to validate the CSA in laboratory studies typically has been indirect calorimetry (7, 10, 11, 17).

The authors are with the Departments of Kinesiology and Osteopathic Surgical Specialties at Michigan State University, East Lansing, MI 48824.
The CSA has also been validated in the field by comparing it to HR telemetry, which has been shown to be reliable and valid when used with children (5). Using HR telemetry as the criterion measure, studies have shown the CSA to be a moderately to highly valid instrument \((r = 0.50–0.74)\) for PA measurement (8) and that the CSA is sensitive enough to detect intensity changes of everyday activity performed by children (9). In addition, the CSA has been validated in pre-school children during free-play using direct observation (6).

Despite numerous validity studies in the laboratory and the field, limited research has been done to validate the use of the CSA to monitor exercise intensity levels during specific sport activities. The ability to distinguish between different intensities during a specific activity will help researchers determine whether the children are engaged in light, moderate, or vigorous activity while playing a given sport. This issue is relevant since much of children’s PA is achieved through playing sports. Pate et al. (12) found that a large percentage of youth in the United States (70% of males and 53% of females) engage in at least one sport either on a school or recreational team, according to data derived from the Youth Risk Behavior Survey.

The purpose of this study was to evaluate the validity of the CSA for estimating PA performed at different intensity levels during boys’ basketball practice. Criterion measures used in this study were the Children’s Activity Rating Scale (CARS) direct observation method and HR monitoring.

**Methods**

**Subjects**

Ten boys (age = 12.8 ± 0.4 yr, height = 166.8 ± 10.2 cm, weight = 59.0 ± 15.6 kg, BMI = 20.9 ± 3.7 kg/m\(^2\)) who played on a junior high school basketball team volunteered to participate in this study. Prior to data collection, each subject and his parent/guardian gave written assent and informed consent. The study was approved by the University Committee on Research Involving Human Subjects (UCRIHS) at Michigan State University.

**Protocol**

Practice sessions were not modified for the study and were similar to others in which the team participated throughout the season. The practices included a variety of different activities, including warm-up exercises, ball handling and shooting drills, running drills, and scrimmages. This strategy ensured that every type of basketball activity and intensity level would be encountered by each subject.

Each subject was monitored continuously using the CSA, CARS, and HR telemetry during a 55-min practice session. The CSA and HR receiver watch were placed in a small pouch on each subject’s right hip. The HR transmitter was placed around the subject’s chest and secured with an elastic strap. Each subject’s PA was measured continuously throughout the entire practice.

**Instrumentation**

**Computer Science and Applications, Inc. Accelerometer.** The CSA (Shalimar, FL) is a uniaxial accelerometer. The accelerometer is a very small device, measuring 6.6 x 4.3 x 1.5 cm and weighing 70 g. The CSA is initialized using a
Reader Interface Unit (RIU) attached to a PC. Predetermined time periods (epochs) are set, as well as time and day, prior to beginning data collection (4). The CSA detects movement through the use of a piezoelectric plate that picks up acceleration signals as it moves. The CSA records activity counts by first filtering and then digitizing acceleration signals. These signals are converted to a numerical value or count, and the counts are summed over each epoch. After the activity count for an epoch is recorded, the device is automatically reset to zero. For this study, epoch intervals were set for 1 min. Information from the CSA was downloaded to a PC after the data collection was completed.

**Children's Activity Rating Scale.** This scale is used for direct observation of children's physical activity (13). CARS uses a 1 through 5 scale to classify and discriminate between different activity intensities. Level 1 categorizes stationary or no movement. Level 2 is some movement (arms or trunk) while stationary. Level 3 involves slow or easy-paced translocation. Level 4 is medium/moderate translocation. Level 5 represents very fast/strenuous activity. A CARS value was recorded each time there was a change in intensity level or a change in activity. CARS values were then averaged each minute to determine an overall activity level. A single investigator performed all observation measures during the study. She was trained in the CARS technique by observing adults and adolescents during basketball games and practices prior to initiating the study.

**Heart Rate Telemetry.** The Polar Vantage XL telemetry system (Polar CIC Inc.; Port Washington, NY) was used to record HR during this study. HRs were recorded continuously and values were averaged over 1 min. HR values were saved on a file on the Polar watch receiver and downloaded to a PC after the practice session was completed.

**Statistical Analysis.** Validity of the CSA was determined in two ways. First, Pearson product moment correlations were performed between CSA and HR using minute-by-minute values. Data from each minute were analyzed as a group average, then on an individual participant basis. Next, subjects' CSA and HR values were categorized by CARS rating of each practice minute. Thus, each minute (total of 55 min for each subject) of CSA and HR values were placed in one of five CARS categories. Group averages for CSA and HR were analyzed by a repeated measures ANOVA to determine whether they differed by CARS level. Due to multiple comparisons, statistical significance was set using an alpha level of $P < .01$.

**Results**

Correlational analysis of group data (550 data points) showed a moderate to good ($r = 0.60; P < .001$) relationship between HR and CSA values (See Figure 1). When data were analyzed for each individual participant, significant correlations were found between HR and CSA values ($r = 0.54–0.81; P < .01$) in nine of the ten subjects. The tenth subject ($r = 0.24$) did not participate in many drills during the majority of practice, which may have led to the lower correlation (personal observation by DPC).

Tables 1 and 2 show the mean and standard deviations for CSA and HR values and time spent at each CARS level. Approximately 92% of the 55-min basketball practice was spent at CARS levels 2, 3, and 4. Only 8% of practice time was classified as level 1 or level 5 activity. Thus, only CARS levels 2, 3, and 4 were included in ANOVA procedures.
Figure 1 — Correlation between HR (b · min⁻¹) and CSA counts using 55 data points from each of 10 participants \(r = 0.60; P < .01\).

Table 1 CSA Values and Time Spent at Specific CARS Levels

<table>
<thead>
<tr>
<th>CARS Level</th>
<th>CSA Value (Counts)</th>
<th>Time at each CARS level (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ± SD</td>
<td>Range</td>
</tr>
<tr>
<td>1</td>
<td>2706 ± 3504</td>
<td>23–7877</td>
</tr>
<tr>
<td>2*</td>
<td>1628 ± 1476</td>
<td>1–7493</td>
</tr>
<tr>
<td>3*</td>
<td>2769 ± 1878</td>
<td>110–12,027</td>
</tr>
<tr>
<td>4*</td>
<td>3510 ± 1841</td>
<td>0–14,178</td>
</tr>
<tr>
<td>5</td>
<td>3352 ± 2326</td>
<td>47–10,945</td>
</tr>
</tbody>
</table>

*Indicates that the HR values in CARS levels 2–4 were significantly different \(P < .001\); CARS = Children’s Activity Rating Scale; CSA = Computer Science and Applications, Inc.

ANOVA revealed significant differences \(P < .001\) in CSA and HR values at each of the three CARS levels. Specifically, as CARS level increased from 2 through 4, CSA activity counts and HRs increased as well.

**Discussion**

The purpose of this investigation was to determine the validity of the CSA accelerometer for estimating PA in boys during basketball practice. Basketball is a sport that consists of many activities performed at various intensities over the course of a practice or game. Activity can be intense, with participants in constant motion.
Basketball also has moments where very little activity is being performed, such as during free throw shooting. Because of this, a single MET value classification for basketball (or other sports) may not provide an accurate account of the actual PA intensity level for a given game or practice. Any measurement method that could more precisely discriminate among various intensity levels would be of benefit to researchers studying PA during youth sports.

Basketball is an appropriate activity to study since it includes a variety of movement intensity patterns similar to those found by Bailey et al. (3) when they observed the level and tempo of children’s PA. Children’s activity levels are highly transitory. Patterns of activity normally include rapid spurts of very intense activity interspersed in activities of low and moderate intensity and varying duration (3). Since the CSA was able to discriminate between intensity levels as categorized by CARS during basketball practice, the CSA may be able to distinguish between intensities experienced by children during other normal everyday PA choices.

Previous field studies have used HR telemetry or recall as criterion measures (6, 7, 11) to evaluate the validity of CSA. Using HR, results have shown moderate to high validity when compared to CSA (8). However, when using self-report as a criterion measure, results revealed only poor to moderate correlation with the CSA (9). Some investigators have suggested that low intensity activities tended to be overestimated, while vigorous activities were underestimated when compared to activity diaries (14). We found good overall agreement between the CSA and HR measures (Figure 1). This was true both for group data and analysis of individual subject profiles.

A unique feature of our investigation is that it is the only validation study of the CSA accelerometer that has used direct observation (CARS) as one of the criterion measures in adolescent children. Direct observation was used to validate the CSA in young children (ages 2–4), and results showed a high correlation with CSA counts ($r = 0.87$) (6). The investigators examined group values, whereas we were able to analyze this relationship on both group and individual levels. Direct observation allows the researcher to observe and record what the subject is doing at all times while being monitored during PA. Although the intensity level of an

### Table 2  HR Values and Time Spent at Specific CARS Levels

<table>
<thead>
<tr>
<th>CARS Level</th>
<th>HR Value (b - min$^{-1}$)</th>
<th>Time at each CARS level (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ± SD</td>
<td>Range</td>
</tr>
<tr>
<td>1</td>
<td>146 ± 25</td>
<td>121–167</td>
</tr>
<tr>
<td>2*</td>
<td>134 ± 23</td>
<td>89–196</td>
</tr>
<tr>
<td>3*</td>
<td>146 ± 26</td>
<td>72–195</td>
</tr>
<tr>
<td>4*</td>
<td>159 ± 18</td>
<td>98–199</td>
</tr>
<tr>
<td>5</td>
<td>160 ± 21</td>
<td>119–197</td>
</tr>
</tbody>
</table>

*Indicates that the HR values in CARS levels 2–4 were significantly different ($P < .001$); CARS = Children’s Activity Rating Scale; HR = Heart Rate.
activity such as basketball or everyday PA may be variable over time, the CARS should be able to account for these changes.

All CSA and HR values were grouped according to their respective CARS levels based on the investigator’s direct observations. Results showed that CSA increased significantly from CARS level 2 to 3, and again from 3 to 4. This is further evidence that the CARS provides a valid measurement of PA performed during a typical basketball practice and sensitive enough to discriminate between the different intensity levels that exist as part of the game.

Our results showed that very few data points were categorized as levels one and five using the CARS. This is because the boys spent little time either sitting or standing completely still or engaged in all out sprint activity. The few data points recorded as level 1 CARS showed very high CSA and HR values with large variability. This may be due in part to misclassification of the CARS level by the investigator. In addition, CSA values are summed and not averaged. Therefore, if the subject spent any portion of the given minute doing anything other than sitting completely still, the CSA value would be inflated. Since level 5 CSA values were lower than those of level 4, some minor misclassification may have occurred here also. Most level 5 classifications were given during minutes where sprinting occurred. For level 5 CSA values, if any portion of the minute was spent at a level lower than five, then the CSA count may not be as high as the value that would be recorded if the entire minute was spent in all-out sprint activity. In any event, the fact that so few minutes were spent at level 5 makes any speculation tenuous.

As was the case with CSA readings, HR increased significantly as CARS levels progressed from 2 to 4. However, we feel that the HR values may overestimate the true PA intensity performed during basketball practice. According to our CARS evaluation, nearly half (47.5%) of the basketball practice was played at levels 2 and 3 where little body movement and/or only slow translocation occurred. Heart rate values averaged ~140 b · min⁻¹ during this time (Table 2). Although a HR of 140 b · min⁻¹ is considered to be a lower limit “cut point” for “hard” activity by some investigators (1, 2), this was clearly not the case in our study. What most likely occurs is that the HR value increases during a flurry of activity during a minute of practice. However, direct observation may reveal that the majority of the minute was spent at a lower intensity with little body movement (CARS 2 or 3). Thus, the HR value would likely be inflated since it may take some time for it to return to the “true” steady-state level.

In summary, the CSA appears to be a valid instrument for determining PA level during activities where intensity is changing constantly. The CSA is sensitive enough to record counts based on the degree of movement and should provide an accurate estimate of the amount of activity being performed, without being inflated as would be the case with HR. Further research is needed to determine whether these results can be duplicated and expanded to other sports and activities.

References


**Acknowledgments**

We would like to thank the Centers for Disease Control and Prevention (CDC) for the use of their CSA accelerometers. We would also like to thank the West Ottawa School District for letting us conduct the study in their school and the Harbor Lights 7th Grade basketball team for participating in the study.