# ACCURACY OF THE POSITIONAL ACTIVITY LOGGER#2 (PAL2) TO IDENTIFY HUMAN POSTURE AND MOVEMENT

**Noel Lythgo[1,2], Amanda Benson[2], Brett Gordon[2]**

**[1]University of Melbourne, Rehabilitation Sciences Research Centre, Melbourne, Australia**
**[2]RMIT University, School of Medical Sciences, Discipline of Exercise Science, Melbourne, Australia**

This study investigated the accuracy of the Positional Activity Logger 2 (PAL2, ProMed Pty Ltd) to identify activity. Eighteen healthy adults participated in this study. Activities were performed three times in random order for durations ranging from 10 to 110 s and were simultaneously recorded by a PAL2 (10 Hz) and Vicon System (120 Hz). The PAL2 correctly identified all activities. Significant duration differences were found for lying, running, sitting and standing (p=0.001). No significant duration differences were found for walking. Mean absolute errors ranged from 3.27 to 5.40 s. The validity of the PAL2 was also assessed with ICCs. It was found to be high for lying and running (ICC=0.87, ICC=0.94, p=0.0001), good for sitting and standing (ICC=0.74, ICC=0.76, p=0.0001) yet low for walking (ICC=0.58, p=0.001). Overall, the PAL2 exhibited good accuracy.

**KEY WORDS:** physical activity, posture, movement, accelerometer, Vicon.

## INTRODUCTION:

Traditional methods of monitoring physical activity have used questionnaires and activity logs. These methods, however, are subjective (Yang & Hsu 2010) and have been found to be invalid in recording light to moderate activity (Richadson, Ainsworth, Jacobs, & Leon, 1996; Wareham & Rennie 1998; Westerterp, 2009). Simple pedometers have also been used to estimate activity but these devices provide limited information. An investigation of the accuracy of ten common pedometers found the majority to underestimate step count whilst overestimating the distance covered when walking at slow speeds (Crouter, Schneider, Karabulut, & Bassett, 2003). Slow speed walking is a common characteristic of people with chronic medical conditons.It is important to accurately monitor physical activity in both pathological and non-pathological populations. Sub-optimal physical activity levels and increased sedentary behaviours are implicated in the rise in obesity and the development of obesity related disorders such as metabolic syndrome and type 2 diabetes (Hamilton, Hamilton, & Zderic, 2007; Healy, Dunstan, & Salmon, 2008). Recent studies show the importance of monitoring sedentary behaviour with increased sedentary time found to be associated with increased plasma glucose levels in healthy Australian adults who spent 57% of awake time engaged in sedentary behaviour over a 7-day period (Healy, Shaw, Dunstan, Zimmett, Salmon, Owen, & Cerin, 2007). More recently, television viewing time has been found to be positively correlated with 6-year mortality rates in a study involving a large sample of Australian adults (Dunstan, Barr, Healy, Salmon, Shaw, Balkau, Magliano, Carmeron, Zimmet, & Owen, 2010). Relative to those watching less than 2 hours of television per day, there was a 46% increased risk of all-cause and an 80% increased risk of cardiovascular disease mortality in those watching 4-hours or more of television per day. These increases were independent of smoking, blood pressure, cholesterol, diet, leisure-time exercise and waist circumference. In recent years, accelerometers have become smaller and less expensive. This has led to the development of a number of physical activity monitors. These include the Intelligent Device for Energy Expenditure and Activity (IDEEA, Zhang, Pi-Sunyer, & Boozer, 2004), the AMP331, the Actigraph model 7164 (Actigraph, Penascola, FL) and more recently the Physical Activity Logger#2 (PAL2, Pro Med Pty Ltd) which is an improvement on the Physical Activity Logger#1 (PAL1). The IDEEA has been shown to be a suitable method for estimating energy expenditure during physical activity and the AMP331 has been shown to to be a valid instrument for the collection of gait data during over-ground walking but not treadmill walking (Lythgo, Edbrooke, Goldsworthy, Friedman, & Denehy, 2009). The Actigraph measures sedentary and physical activity time (light, moderate, vigorous) but the sedentary data should be treated with caution (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2001). The PAL2 measures the type of posture (e.g. stand, sit, lying) and gait (e.g. walk, run) but has not been independently evaluated. The fundamental aim of this investigation was to assess the validity and reliability of the PAL2 to record physical activity and sedentary behaviour (sitting, lying, standing, walking and running). The activty recorded by the PAL2 was simultaneously recorded by a VICON Motion Measurement System (Oxford Metrics Group, UK) which is considered to be a "gold standard" measure of human motion.

**METHODS:** Eighteen healthy adults (30.4 ±13.1 y; 1.73 ±0.11 m; 71.4 ±15.2 kg) participated in this study. Ethics approval was obtained from The University of Melbourne. Written informed consent was obtained from all participants. Exclusion criteria were any neurological, musculo-skeletal or other medical condition known to affect gait. Participants attended the Movement Laboratory based at the Rehabilitation Sciences Research Centre. The Experimental protocol involved three tasks (described below) completed over a period of about 60 minutes. For each task, participants wore shorts, a t-shirt and athletic footwear. The first task was used to determine the threshold level for posture transitions (e.g sit-to-stand, lying-to-stand), the second task was used to identify the threshold level for gait transitions (i.e. walk-to-run, run-to-walk) and the third task was used to assess the PAL2. For each task, the PAL2 holder (a stretch elastic Velcro fastened strap) was attached around the right thigh with the pocket (into which the PAL2 was inserted) positioned on the lateral aspect of the leg (Figure 1).

Task 1: Sit-to-Stand: Each participant completed a set of twelve chair rises from a standard chair. Each position (sit and stand) was held for a period of 5 seconds.

Task 2: Determination of Walk-to-Run Transition Point: Participants began walking on a treadmill set at a speed of 4 km/hr. Each 15 seconds, the treadmill speed was increased by 0.2 km/h until the participant began to run (walk-to-run transition point). Participants then completed six trials in the following manner: walk for 30 seconds on the treadmill at a speed 0.2 km/h below the walk-to-run transition point. The speed of the treadmill was then set 0.2 k/hr above the walk-to-run transition point. Participants then completed 30 seconds of running on the treadmill. This task was used to determine the treadmill speed for task three.

Task 3: Lying, sit, stand, overground walk, treadmill run: Five passive spherical reflective markers (14 mm diameter) were placed on both of the participants' runners (toe and heel areas) and sacrum (mid-posterior superior iliac spine). Non-allergenic double-sided tape was used to attach these markers. Participants completed a series of activities over 18 minutes. Initially, the PAL2 (10Hz) and Vicon (120 Hz) systems were synchronised by the participants performing a jump onto an AMTI force plate (Advanced Mechanical Technology, Inc.,Watertown, MA) embedded in the centre of the laboratory. The activities were lying, sitting, standing, overground walking around a 14.7 m circuit (3.2 m length straights, 4.2 m length curves) at a self-selected speed, and running (0.2 km/h above transition speed) on a level motorised treadmill. The 14.7 m circuit constituted the maximum capture area of the VICON. The lying, sitting, standing and running activities were performed inside the circuit. The activities were performed in random order and activity durations were randomised with periods ranging from 10 to 110 seconds: (lying: 30.5 ± 6.7 seconds; treadmill running: 57.9 ± 10.3 seconds; sitting: 29.2 ± 3.8 seconds; standing: 30.1 ± 6.5 seconds; overground walking: 60.5 ± 10.4 seconds). The 3D coordinate position of the markers were recorded by a Vicon Motion Analysis System and accompanying Nexus software (version 1.7.1).

**Figure 1: PAL2 placement.**

Data Analysis: The accelerometer data recorded by the PAL2 device was downloaded to a PC at the end of each test session. Once downloaded, it was analyzed by the PAL2 PC software. This process involves two stages. The first stage involves the identification of threshold levels for tasks one (sit-to-stand) and two (walk-to-run transition point). In the second stage of the analysis, movement or posture type, onset, duration and frequency was extracted from the data. Equivalent information was manually extracted from the Vicon Motion Analysis System by visual inspection. Descriptive statistics were generated for the activity duration data generated by each system. A repeated measures MANOVA was used to compare the data in order to assess the accuracy of the PAL2 system to record movement and posture. Validity was also examined by calculating intraclass correlations (ICC) for each activity. These correlations compared the PAL2 and VICON data, using VICON as the criterion measure.

**RESULTS:** The activity identification rate of the PAL2 was 100%. The descriptive statistics for the activity duration data are listed in Table 1. Significant duration differences were found for lying, treadmill running, sitting and standing. The mean absolute errors for these activities were 3.27 s, 4.92 s, 4.22 s and 4.66 s respectively. The walking data was not significantly different with a mean absolute error of 5.40 s. The validity of the PAL2 was also assessed with ICCs. The validity (Table 2) was high for lying and running, good for sitting and standing yet low for over ground walking (ICC=0.58, p=0.001).

**Table 1**
**Descriptive statistics for each movement and posture**

| Activity | PAL2 | Vicon | N | p-value | Absolute Error |
|---|---|---|---|---|---|
| Lie (s) | 30.46 ± 6.68 | 28.06 ± 6.71 | 54 | 0.001 | 3.27 ± 2.66 |
| Run (s) | 57.85 ± 10.33 | 53.91 ± 10.01 | 54 | 0.001 | 4.92 ± 3.72 |
| Sit (s) | 29.20 ± 3.83 | 25.95 ± 4.27 | 50 | 0.001 | 4.22 ± 2.50 |
| Stand (s) | 30.10 ± 6.52 | 26.42 ± 4.94 | 51 | 0.001 | 4.66 ± 4.23 |
| Walk (s) | 60.46 ± 10.38 | 59.68 ± 5.93 | 54 | 0.532 | 5.40 ± 7.44 |

**Table 2**
**ICC statistics**

| | ICC | Sig |
|---|---|---|
| **Lie** | 0.87 | 0.0001 |
| **Run** | 0.94 | 0.0001 |
| **Sit** | 0.74 | 0.0001 |
| **Stand** | 0.76 | 0.0001 |
| **Walk** | 0.58 | 0.001 |

**DISCUSSION:** The PAL2 identified all five activities for each participant with a 100% success rate. It correctly identified movement and posture type. Although significant duration differences were found for lying, treadmill running, sitting and standing (p=0.001), the mean absolute errors were small ranging from 3.27 to 5.40 s. The results show that the error in the PAL2 system is acceptable and that it can be used to monitor physical activity and sedentary behaviour but data should be treated with some caution. The validity of the PAL2 was also assessed with ICCs. It was found to be high for lying and running, good for sitting and standing yet low for over ground walking.

**CONCLUSION:** Overall, the PAL2 exhibited good accuracy. It can identify movement and posture type with 100% accuracy. Significant differences were found for the lying, running, sitting and standing duration data but absolute errors were relatively small. These data, however, should be treated with some caution given the variability shown in some activities.

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