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PEDOMETER AND ACCELEROMETER IN ASSESSING PHYSICAL ACTIVITY AMONG CHILDREN AND ADOLESCENTS

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EXECUTIVE SUMMARY

This review was requested by the Technical Working Group for Research, Family Health Development Division, Ministry of Health Malaysia.

Patterns of children's physical activity have been documented by direct observations to be variable and of limited duration. Pedometer and accelerometers are commonly used devices for assessment of physical activity both in children and adults. Pedometer is a relatively simple electronic device that records the acceleration and deceleration of movement in one direction. Accelerometers are more complex electronic devices that specifically measure accelerations produced as a body segment or limb part moves through space. There are three types of accelerators which are uni axial, tri axial or omni axial.

The objective of this review was to assess the safety, effectiveness and cost effectiveness of pedometers and accelerometers in measuring physical activities in children and adolescents.

Seven articles were selected. The studies were carried out among children aged 3 to 16 years old and majority of them had small sample size. Four studies were performed within a structured physical activity program and three studies were carried out within daily physical activity. In terms of accuracy, evidence showed that pedometers' and accelerometers' models used in these studies such as tri-axial Tritrac-R3D, Yamax Digi-walker (model DW-200 and SW701), Walk4Life (model LS250),WAM accelerometer (model 7164),CSA Actigraph monitor (model 7164), Actiwatch® activity monitor and Actical accelerometer were valid instruments for measuring of physical activities except, Caltrac AC accelerometer**.** Mini Mitter MM Actiwatch (model AW16) accelerometer was only valid when it was used to assess physical activity under controlled research setting but not under free-living condition. When comparing tri-axial Tritrac-R3D, uni-axial WAM accelerometer (model 7164) and Yamax Digi-walker DW-200 pedometer in the same study; evidence showed that the best single device was tri-axial Tritrac-R3D accelerometer. It was also reported that the measurement of physical activity was affected by the site of attachment of the devices, the duration of physical activities assessment as well as whether the study was carried out within a structured physical activity program or daily physical activity. However, the main disadvantage of accelerometer is cost.

Based on the findings of the above review, among the pedometers and accelerometers,tri-axial Tritrac-R3D accelerometer can be recommended, as evidence showed that it is the most accurate device for the estimation of variety of physical activity in children. However, cost should also be considered before applying this device in a nationwide study.

PEDOMETER AND ACCELEROMETERS

1. INTRODUCTION

Physical activity is defined as a complex set of behaviors that encompass any bodily movement produced by skeletal muscles that result in energy expenditure[1]. More than 30 different methods of assessing physical activity have been identified but the reliability; objectivity and validity of many of these methods have not been established with children and adolescents[2].

Patterns of children's physical activity have been documented by direct observations to be variable and of limited duration. Children appear to transition into and out of levels of activity quickly, and prolonged activity is not a part of their natural activity pattern[3].

There are three types of measures of physical activity in children and adolescents: primary or criterion standard, secondary and subjective measures as shown in figure 1[4]. Pedometer and accelerometer are secondary or objective methods of physical activity assessment.

1.1 PEDOMETER

Pedometer is a relatively simple motion sensor and electronic devices that record the acceleration and deceleration of movement in one direction[3]. It is normally use to estimate mileage walked and/or steps taken over a period of time[2]. Leonardo da Vinci is credited with the intervention of pedometer; his 15th century drawings described the basic principles behind the mechanical pedometer of today. Thomas Jefferson is thought to have brought the first pedometer to the United States from France. The older mechanical-style pedometers are less accurate than the electronic pedometers developed in the past 10 years[5].

Pedometers were initially used by pro athletes, but they are now becoming popular amongst regular fitness people as well. People use pedometers as a motivator in a battle against themselves, because pedometers can give encouragement to complete with oneself in getting fit and losing weight[6]. Typically, the distance recommended for keeping good shape is 6,000 steps a day, while for weight loss we should be doing about 10,000 steps a day[7].

1.2 ACCELEROMETER

Accelerometers-based devices have been employed in human movement study for the past 30 years. One of the first accelerometers was the Large-Scale Integrated (LSI) Motor Activity Monitor, developed in the 1970s and early 1980s. Accelerometers are more complex electronic devices that specifically measure accelerations produced as a body segment or limb part movement moves through space[5].

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CRITERION STANDARD
Direct observation
Doubly labeled water (DLW)
Indirect calorimetry

SECONDARY MEASURES
Heart rate (HR)
Accelerometer
Pedometers

SUBJECTIVE MEASURES
Self-report
Interview
Proxy-report
Diary

Figure 1: Different Measures of Physical Activity

2. OBJECTIVES

To assess the safety, effectiveness and cost effectiveness of pedometers and accelerometers in measuring physical activities in children and adolescents.

3. TECHNICAL FEATURES

3.1 PEDOMETER

Basic principles of all pedometers are step counting by sensing the impact of a foot with the ground as a step is taken. There are two types of sensors used in pedometers to sense steps [6].

Most pedometers use a simple pendulum or swing-arm system. This type of system uses a pendulum or swing-arm that makes contact with a post when we take a step, closing the circuit and registering a step in the pedometer. This movement is what sometimes generates the “click” or “rattle” that we hear when we take a step. The calibration of the movement is what is most important, and this is determined by a number of design factors such as the length of the arm, weight of the arm, post type / position, and tension of the spring that supports the arm. Some pedometers allow us to adjust the sensitivity of the movement, usually with a button or slide that adjusts the tension of the arm support spring. Most of the established manufacturers have time-proven movements. It also incorporates an electronic filter circuit that prevents most non-step movements from being counted as steps. This filter is really designed for the all-day wearer, who is concerned about steps being counted while riding in a car, or sitting at their desk at work. An electronic filter is the only way to eliminate counting false steps[6].

Some new pedometer designs are using accelerometer technology to sense step impact. These pedometers sense by sensing impact as steps are taken. This technology has no moving parts, resulting in quiet, reliable operation. The Omron HJ-112 pedometer uses this technology, where a pair of electronic sensors along with sophisticated internal circuitry as its foundation for counting steps. The two sensors are placed 90 degrees apart, therefore allowing the pedometer to work equally well in any position. The Omron HJ-112 is the only pedometer that can be placed in a pocket or purse[6].

Current pedometers are battery operated [3]. Pedometers can be in different models with different features. The best pedometers can calculate and display other interesting features such as distance, calories burned, speed, elapsed time, steps per minute, and function as a stopwatch and alarm [8,9].Distance is calculated by multiplying the number of steps by the stride length (distance= steps x stride length). Walking speed, height, age, gender, and /or physical impairment can all influence stride length throughout development [5].

Other than waist or hip, pedometer also can be worn or clipped to the top of our shoes, right below the ankle, or even in our back pocket [6].Different pedometer brands and models are presented in Table 1 [9,10,11].

TABLE 1: SUMMARY OF DIFFERENT PEDOMETERS

DEVICES (brands/ models)	**FEATURES**	**PRICES**	**ATTACH-MENT**
Yamax® digi-walker 701 pedometer*	Counts steps and estimates distance based on average stride, which can set in increment of 0.25 feet. Estimate calories burned[9].	\$23.90-\$24.95	waist
Yamax® digi-walker SW 200 pedometer*	Only count steps, but it considered gold standard by the researchers. Having reset button[9].	\$18.9-19.49[10]	waist
Omron HJ-112 pedometer	Counts step, calculates distance, and calories burned, also track aerobic steps separately when walking or jogging more than 60 steps per minute or more than 10 minutes continuously. It has 7-days memory absolutely silent, no clicking or ratting [9].	\$19.49	Belt or put it in the pocket, clip on the bra, but perpendicular to the ground
Omron HJ-720 ITC pedometer	All featured pedometer (steps, distance,calories) that allow us to upload it all, to enjoy graphs and charts of steps, aerobic steps, distance calories and fat burned. It advanced design because it tolerates more tilt than many, and silent. Can upload the data on the computer to set the goals and see the progress [9].	\$31.48	waist
New-lifestyles NL-2000 pedometer	Can count steps and estimate calories burned. It has seven days memories[9].	\$59.95	waist
Sportline fitness pedometer 360	Small, quiet and accurate. The dual-line display shows distance and other data-steps, calories, speed, step-per-minute, time of day. The flip case protects the button[9].	\$24.95	waist

Sportline 330 pedometer	Only counts steps and inexpensive. Cover prevents user from accidentally resetting it. Can count steps and walking time, and calculate calories burned and distance [9].	$ 9.95	waist
Freestyle Pacer Pro pedometer	It is tiny, and quiet. It counts steps, measure time spent exercising, calculates distance and calories and speed. It has flip case to prevent pushing buttons accidentally [9].	$16.99-$23.99	waist
Sportline Talking Pedometer	The voice announcement informed the calories burned, number of steps taken, distance traveled and total time[9].	$19.99	waist
Walk4life* (LS2505, LS2505, LS2515,and LS2525)	Small, quiet, counts steps, estimates distance and calories. Very secure clip[9].	$30.00[11]	Leg

*-Has pediatric application

3.2 ACCELEROMETERS

The principle of accelerometer is to assess and quantify the motion or movement associated with physical activity. Acceleration is a change in velocity with respect to time (m/s^2), enabling accelerometers to quantify intensity of movement, frequency and duration of physical activity, and often also a step value, per epoch [3,12]. Epoch is a time sampling interval used to assess physical activity. Piezoelectric transducers and microprocessors are used to convert recorded accelerations to a quantifiable digital signal referred to as ‘counts’[4].

Majority of accelerometers are uni-axial and are sensitive to movement in the vertical axis but some are also sensitive to acceleration in the antero-posterior and/or lateral planes (bi-axial or tri-axial). Omni-directional accelerometers theoretically assess acceleration in multiple directions; however, as they are most sensitive to movement in the vertical plane, they are fundamentally uni-axial[12]. A few brands of accelerometers with its prices and site of attachment are listed in table 2 [3,5,13,14,15,16,17,21,22,23] .

TABLE 2: SUMMARY OF DIFFERENT ACCELEROMETERS

DEVICES Brands/models	FEATURES	PRICES	ATTACH-MENT
Caltrac accelerometer*	Uni-dimensional, measures the degree and intensity of movement in the vertical plane, and size of a personal pager[17].It also able to measure cumulative total steps, settings for different sport activities, and have replaceable batteries[3].	$ 67-87[13]	Waist
Actiwatch® Mini-Mitter*	Uni-axial, small, lightweight activity monitors.Long term activity monitoring.[5,22].Built from a cantilevered rectangular piezoelectric bimorph plate seismic mass, which is sensitive to movement in all directions accelerometer parallel with longest dimension, is newer version actical and it is smaller than actigraph[14] .	A credit of $1,500 (one competitive actigraphy device, reader and software package with cables and manual)	Waist, wrist
CSA Actigraph monitor (model 7164; Computer Science and Applications, Shalimar, FL)*	Uni-axial accelerometer that measures accelerations in the vertical plane[21].	$400 and $929 for the starter pack[15].	Hip,ankles, wrist
Actiwatch MM* (model AW16; Mini-Mitter, Bend, OR)	Sensitive to movement in all directions, but most sensitive in the direction parallel with the longest dimension of the case [21].	Not available	leg and waist
StepWatch*	Sensor for step movement, calibrate to individual gait, sensitivity, time series data up to 6 week, sealed. No visual feedback to wearer, pager size. Requires dock and computer software to download, export to Excel file, validated to steps, 5–6 years battery life[3].	Not available	Waist, wrist

The Actical accelerometer (Mini Mitter)*	Has an omni-directional sensor and is capable of measuring movement in one plane. The sensor functions via a cantilevered rectangular piezoelectric bimorph plate and seismic mass, and it is capable of detecting movements in the 0.5- to 3-Hz range. Voltage generated by the sensor is amplified and filtered via analog circuitry. The amplified and filtered voltage is passed into an analog to digital converter, and the process is repeated 32 times per second (32 Hz). The resulting 1-second value is divided by four, and then added to an accumulated activity value for the epoch. The Actical is the smallest ccelerometer available (28 x 27x10 mm, 17 g) and is water resistant. It has replaceable batteries[23].	Not available	Waist, wrist, and ankle
Tri-axial R3D*	Three dimensional mediolateral (*x*), anteroposterior(*y*), and vertical (*z*) dimensions, as well as the vector magnitude[16].Able to preset 1-min epochs, 60-day battery life. Requires separate power source to charge[5]. The size of the device is 11.1 x 6.7 x 3.2 cm the weight is 170 g [16].	Not available	Waist

*-Has pediatric application

Figure 2: Digi-Walker SW-200 by Yamax, one type of pedometer

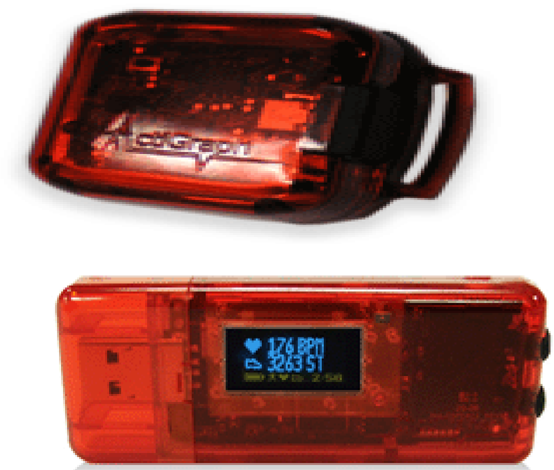

Figure 3: The Actiwatch (above) and ActiGraph (below), types of accelerometer.

4. METHODOLOGY

4.1 SEARCH METHODS

Literature were searched through electronic databases, which included Pubmed, OVID, Proquest, Ebscohost, EBM Reviews for controlled trials, Cochrane database on systematic review, Cochrane Clinical Trial Registry, Science Direct, Springer Link, and General Databases Such as Google and Yahoo.

The search strategy used the terms, which were either used singly or in various combinations: “pedometer”OR “accelerometer” OR “physical activity” OR “monitoring”

OR “assessment” OR “motion sensors”, “safety” OR “safe” OR “adverse effect” OR “harm*” OR “effect*” OR “toxicity”, OR “cost effectiveness” OR “cost analysis” OR econom* AND “child*” OR “adolescent”.

4.2 SELECTION OF STUDIES INCLUDED/EXCLUDED

All primary papers, systematic reviews or meta analysis pertaining to safety, effectiveness and cost effectiveness on usage of pedometer and accelerometer on human were included in this study.

A critical appraisal of all relevant literature was performed and the evidence level graded according to the Oxford Centre for Evidence-based Medicine Levels of Evidence (May 2001) for diagnosis.

5. RESULTS AND DISCUSSION

There were many studies done to validate the performance of pedometers and accelerometers.

SAFETY

No retrievable evidence on the safety aspect of these devices.

5.1 EFFECTIVENESS

Based on the evidences retrieved, pedometer and accelerometers were commonly used devices for assessment of physical activity both in adults and children. Seven studies were included in the evidence tables, involving children aged from 3 to 16 years old. These studies reported the accuracy and reliability of pedometers and accelerometers in children and adolescents only. The reference standard used in those studies were either Doubly Labeled Water, direct observation (System of Observing Fitness Instruction Time, SOFIT) or (Children’s Activity Rating Scale, CARS), indirect calorimeters (expiration respiratory gases VO_2 or oxygen uptake). However, majority of the studies had small sample size[16,17,19,21,22,23] .

The studies were performed under two different settings. Structured physical activity program was a condition when the activities were planned by the researchers or activities were performed on treadmill walking in a laboratory setting[16,21,23] .Another setting was when the children’s daily physical activities were observed by the trained researchers or recorded by the devices[17,18,19].The devices were attached at their bodies and parents were advised to supervise the children at home. They had to come back to the research centre for data reading at regular intervals.

5.2.1 PEDOMETERS

Scruggs et al. in this study validated pedometers Yamax SW701 and Walk4life LS2505 against direct observation, SOFIT [20].The result showed strong and significant relation between steps count per minute by SW701 and LS2505 pedometers with direct observation physical activity time, (SOFIT) (r = 0.912 and r = 0.922 respectively). The relationship between SOFIT and physical activity time (minute) by LS2505 pedometer was also significant with r = 0.848. SW701 and LS2505 pedometer step outputs have clinically acceptable agreement with r = 0. 977. The accuracy was affected by the types of physical activities, whether it was continuous or intermittent and at low or high volume [20 level 1b].

5.2.2 ACCELEROMETERS

Johnson et al. in his study, compared Caltrac accelerometer against energy expenditure, DLW[17].The author concluded that Caltrac AC was not a meaningful predictor of AEE in those samples (r = 0.09; P < 0.63). The caloric estimates of energy expended in physical activity derived from the Caltrac AC, were significantly higher in comparison with measured AEE in these free-living children(956 kcal=d vs. 469 kcal=d, respectively, t =5.9, P < 0.001))[17].The children were left unobserved to wear the instrument for 3 days. They may be overtaken by curiosity and handle the Caltrac when it should be around the waist, consequently causing misrepresenting of activity levels[17 level 1b].

Payau et al. in his controlled laboratory and field settings study compared Mini Mitter (MM) Actiwatch (model AW16) and CSA Actigraph monitor (model 7164) against energy expenditure measured by Room Respiration Calorimetric[21].He concluded that the validation of those two instruments against activity energy expenditure (AEE) as well as their calibration for sedentary, light, moderate, and vigorous thresholds, certify these monitors as valid, useful devices for the assessment of physical activity in children[21 level 1b]. CSA accelerometer output was influenced by the place of attachment on the body with r =0.77 ± 0.11. However, placement of the activity monitor on the hip or the leg gave similar results for Actiwatch MM (r = 0.93 ± 0.04)[21] .

Finn and Specker [22 level 1b] also evaluated the Actiwatch® activity monitor against direct observation using the Children's Activity Rating Scale (CARS) under child care setting[22]. Their common activities were classified into five levels. The result showed that within-child correlations between 3-minutes activity counts and 3-minutes Children's Activity Rating Scale (CARS) scores ranged from 0.03 to 0.92 with median of 0.74. The author concluded that Actiwatch® activity monitor was valid instrument for estimation of physical activity in pre school children.

However, Lopez-Alarcon M et al. in another study done under free-living condition found that activity counts obtained with the Actiwatch model AW16 did not reflect total energy expenditure (TEE) (r = 0.27, p = 0.15) or percentage fat mass (r = - 0.03, p = 0.86).This might be due to the fact that relatively long period of study causing subjects engaging in a diverse suite of activities[19 level 1b].

Pfeiffer KA et al. in this study tested Actical accelerometer (Mini Mitter) against metabolic measures, oxygen consumption (VO_2).The result showed that Actical accelerometer is a valid tool for measuring physical activities in young children with r = 0.89 across all activities[23 level 1b].

5.2.3 COMPARING PEDOMETERS AND ACCELEROMETER

Eston et al. in his study compared tri-axial accelerometer (Tritrac-R3D accelerometer model T303), uni-axial accelerometer (WAM accelerometer, model 7164), and pedometer (Yamax Digi-walker DW-200) against oxygen uptake (sVO2)[16.]

The author concluded that the best single predictor of sVO_2 for a variety of children's typical activities was by the Tritrac-R3D activity monitor (R^2 = 0.83, standard error of the estimate =10.3 ml·kg-0.75min-1). Yamax Digi-walker DW-200 pedometer step counts showed better correlation with calorimetry,sVO_2 with ranged of R^2 from 0.62 to 0.65 when placed at hip and ankle but showed low correlation if the pedometer was placed at wrist R^2 = 0.44. WAM accelerator, model 7164 also showed good estimate with R^2 =0.609[16 level 1b].

5.3 COST-EFFECTIVENESS

There was no retrievable evidence on evaluation of the cost–effectiveness of using this technology. However, many authors commented that pedometer is relatively inexpensive technique to assess physical activity as compared to accelerometer as well as other gold standard [4,24,25,26,27]. Kriestie at al. study mentioned that pedometers' and accelerometers' prices ranged from $15.00 to $50.00 and $100 to $ 3,000 respectively[3].

6.0 CONCLUSION

In term of accuracy, evidence showed that all pedometers and accelerometers models used in these studies such as; Yamax Digiwalker (model DW-200 and SW701), Walk4Life (model LS250) pedometers, tri-axial Tritrac-R3D , WAM accelerometer (model 7164), CSA Actigraph monitor (model 7164), Actiwatch® activity monitor and Actical accelerometers were valid instrument for measuring physical activities, except Caltrac AC accelerometer**.** Mini Mitter MM Actiwatch (model AW16) was only valid when it was used to assess physical activity in controlled research setting but not under free-living condition. While comparing tri-axial accelerometer, uni-axial WAM accelerometer (model 7164), and Digiwalker DW-200 in the same study; evidence showed that the best single device was tri-axial Tritrac-R3D accelerometer. It was also reported that the measurement of physical activity was affected by the site of attachment of the devices and whether the study was carried out within a structured physical activity program or daily physical activity. In addition, the duration of measurement of physical activities was also affected. However, the main disadvantage of accelerometer is cost.

7.0 RECOMMENDATION

Based on the findings of the above review, among the pedometers and accelerometers, tri-axial Tritrac-R3D accelerometer can be recommended as evidence showed that it is the most accurate device for the estimation of variety of physical activity in children. However, cost should also be considered before applying this device in a nationwide study.

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