The Effect of Epoch and Cut-point on the Assessment of Physical Activity Levels in Kenyan School Children

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Abstract

The aim of this study was to investigate the effect of using different accelerometer cut-points and epoch on reports of sedentary behavior and physical activity (PA) levels in a group of Kenyan school children. The PA levels of 26 children from the Nandi region of Kenya aged 4-16 years, was assessed for 3 consecutive days using uniaxial accelerometry combined with a PA diary. No significant differences were found in counts per minute (CPM) (753±214, 753±212, 724±220, 723±229, 721±220, 733±212 CPM; P>0.05) or total monitoring time (689±109, 693±110, 693±108, 693±109, 695±108, 693±110 min; P=1.00) across all six epochs. Time spent engaging in sedentary behavior was not effected by epoch or cut-point (Sirard cut-point, 590±87, 592±87, 594±88, 596±89, 598±90, 598±94 min; Reilly cut-point, 573±86, 567±87, 554±85, 554±88, 550±86, 547± 89min; P>0.05), while the amount of light (Sirard cut-point, 38±11, 43±12, 76±22, 79±23, 81±24, 81±23 min; Puyau, 70±20, 87±27, 104±35, 111±38, 120±34, 123±42 min; Pate, 596±87, 595±87, 595±87, 597±88, 601±90, 604±94 min; P<0.05) and moderate-to-vigorous physical activity (MVPA) (Sirard, 73±25, 71±26, 37±23, 35±24, 32±24, 28±24; Puyau, 59±22, 52±23, 45±24, 41±25, 38±26, 36±28; Pate, 108±29, 107±40, 110±31, 109±32, 106±33, 102±34 min; P<0.05) were influenced by choice of cut-points and epoch. Shorter epochs, such as 1 and 5 s, resulted in significantly less reported minutes of light PA (Sirard, 1 s 38±11 and 5 s 43±12 min vs. 76±22, 79±23, 81±24 and 81±23 min; Puyau, 1 s 70±20 and 5 s 87±27 vs. 104±35, 111±38, 120±43 and 123±42 min; P<0.05) and significantly more minutes of moderate and vigorous activity (Sirard 1 s 73±25 and 5 s 71±26 vs. 37±23, 35±24, 32±24 and 28±24 min; Puyau 1 s 59±22 vs. 60 s 36±28 min P<0.05). Lower cut-points led to significantly more minutes of light, moderate and vigorous PA compared to higher cut-points (see above; $P<0.05$). In conclusion, choice of cut-points and epoch significantly influences PA classification, where it may be more appropriate to use smaller epochs when assessing PA levels of active children. Additionally, one should be wary when comparing PA calculated using different cut-point values.

Key words: Accelerometry - Kenya - MVPA- objective assessment

Declaration

I declare that the work presented in this thesis is my own and that it has not been submitted for a degree at another institution.

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Contents

1. Acknowledgements

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2. Introduction

During the last decade the United Kingdom has emerged as one of the most obese nations in Europe (Harro and Riddock, 2000). For example, the annual Health Survey for England found that in 2004 19% of boys and 18% of girls aged 2-15 years were obese (Buttriss, 2006). In Scotland the picture is similar, with obesity levels rising from 14.3% of 4-6 year olds and 12.4% of 13-15 year olds in 1993 to 21.1% of 4-6 year olds and 30.3% of 13-15 year olds in 2002 (NHS Quality Improvement study, 2004 Health indicators), with the level of obesity in children expected to continue to rise (Buttriss, 2006). This is of major concern as the majority of obese children remain obese into adulthood (Reilly et al., 2003(a)). For example, Whitaker et al. (1997) found 69% of obese children aged 6-9 years in the USA remained obese in adulthood, while a study by Freedman et al. (2001) reported 77% of obese children remaining obese into adulthood. Additionally, obesity in childhood can increase the likelihood of developing conditions such as diabetes mellitus, cancer, asthma and psychological problems (Reilly et al., 2003(a)). Of particular interest is the association between childhood obesity and increased cardiovascular risk both in childhood and adulthood. A review by Reilly et al. (2003(a)) found that studies consistently reported associations between obesity and many cardiovascular risk factors such as high blood pressure, dyslipidaemia, abnormalities in left ventricular mass, abnormalities in endothelia function and hyperinsulinaemia (See Review Reilly et al., 2003). Additionally low PA compounds these risk factors further, increasing the risk of developing coronary heart disease, diabetes and colon cancer (Sirard et al., 2001; Warburton et al., 2006).

PA can be defined as ‘bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure’ (US Dept Health, 1996). This includes a variety of tasks from daily chores to structured sport activities. A decline in PA is most likely a the main contributing factor to the increasing trend of childhood obesity; but this is very difficult to quantify, as few studies utilise the same methods of assessment and no base line data exist (Dollman et al., 2005). However, the dramatic change in western lifestyles over the last few decades can give an insight into the decline in childhood PA. For example, Black et al. (2001) found that between the 1970’s and the 1990’s the percentage of British children walking to school declined, whereas the percentage of children travelling to school by car rose over the same period. Another study addressing the safety of travelling to school found that the average yearly distance walked by British children had declined by 78 km between 1985 and 1993 and that the distance cycled per year had declined by 16 km (Roberts, 1996). Additionally, time spent engaging in sedentary activities, especially those involving television and electronic games has increased, with recent estimates indicating adolescents in the western world use electronic media for roughly 5 hours per day (Biddle et al., 2004).

In response to this decline in childhood PA, government bodies have created guidelines pertaining to the amount of activity children should be participating in. The consensus statement of the United Kingdom was commissioned in 1997 to explore the current literature in order to make public health recommendations for young people aged 5-18 years (Cavill et al., 2001). This included PA guidelines which recommended that all young people should accumulate at least 60 minutes of at least moderate PA per day (Cavill et al., 2001). The rationale for this is that British children were reaching the current adult recommendation for 30 min of PA on most days of the week, however, the level of obesity in British children continued to rise (Cavill et al., 2001). Additionally, many children possessed risk factors for conditions such as cardiovascular disease, asthma and diabetes and therefore a higher amount of time engaging in moderate PA was deemed necessary in order to gain health benefits and reduces overall body fat (Cavill et al., 2001). The US carried out similar research and came to the same conclusion, in that children should be engaging in at least 60 minutes of at least moderate PA on most days of the week (Cavill et al., 2001:US Dept Health, 1996). The need to quantify PA accurately has seen a rise in techniques used to assess PA in children. PA can be assessed in many ways; common methods include subjective techniques such as observational studies, self/proxy reports of PA and objective methods such as accelerometry, pedometry and heart rate (HR) monitoring.

Direct observation techniques are often used to assessment PA and have been described as 'the most practical and appropriate criterion measure of physical activity and patterns of activity' (Sirard et al., 2001). Many direct observational techniques exist, examples are the Children's Activity Rating Scales (CARS) (Puhl et al., 1990), the Modified Fargo Activity Time Sampling Survey (FATS) (Bailey et al., 1995) and Activity Patterns and Energy Expenditure (APEE) (Epstein et al., 1984). All rely upon trained volunteers observing subjects and noting the intensity, duration and frequency of PA during free living conditions every 10-60 sec over a given time frame (Sirard et al., 2001). The FATS technique, created by Bailey et al. (1995), divides each 12 hour day into 4 hour observational periods in which the child is followed by a trained investigator. Each 4-hour block is then divided into 30 min blocks, within this block a recording of posture and intensity is noted every 3 s in accordance with a coding system developed by the study group. This allows a comprehensive record of posture, intensity, duration and frequency of PA during free living activities in any situation including school or within the home. However this, like all other observational techniques, is very time consuming, the presence of an investigator may interfere with free living activity, especially in children, and the use of investigators to distinguish activity levels also brings in a subjective element which may lead to bias (Phul et al., 1990). Investigators may also miss some PA, especially in children, as their activity patterns are said to be very sporadic and intermittent (Bailey et al., 1995). Additionally the labour intensive nature of this technique (i.e. an investigator must be present at times and data must be further analysed once collected) makes these techniques ill suited to large epidemiological studies.

Other, less time consuming subjective methods include self and interview administered retrospective questionnaires, activity diaries, mail surveys and proxy reports and are therefore often used in large scale population studies (Trost et al. 2007). Such methods are usually employed in large epidemiological studies due to ease of administration, low cost and where objective measures such as accelerometry and HR monitoring are not practical (Trost et al., 2007; Armstrong et al., 2006; Miles, 2007; Sirard et al., 2001). Subjective methods of assessment of PA rely upon subjects recalling perceived PA over a given period of time. Such reports allow the type, duration, frequency and context of PA to be recorded historically (Trost et al., 2007). The main disadvantage of using such methods in children is their inability to accurately recall PA due to reduced cognitive abilities (Sallis, 1991; Baranowski et al., 1984). For example Baranowski et al. (1984) found that children were unable to accurately recall activities and in particular they are unable to quantify the duration of PA (Baranowski et al., 1984). Saris also found that children under the age of 10 years could not reliably give information on activity patterns (Saris, 1985). This is partly overcome by proxy reports. However, these are open to parental bias, Harro et al. found parental PA reports led to the exaggerated reports of MVPA by 1.8 times when compared with HR recordings for the same children (Harro et al., 1997). Additionally, it is impossible for parents or teachers to be with children at all times thus leading to a miss representation of PA missing periods of activity or inactivity (Murphy et al., 1988). Children also tend to take part in unstructured leisure time activities which are difficult for parents and teachers to quantify (Armstrong et al., 2006) and the sporadic nature as described by Bailey et al. (1995) of children's PA, further complicates reports of physical activity as they may be missed. More recently these disadvantages have been over come by using objective methods for the assessment of daily PA levels in large populations. Examples are HR monitoring, pedomtry and accelerometry which all assess PA objectively (Figure 2.1 (a)-(c)). All are small, relatively cheap, 'black box' devices which can be placed on a child and can assess PA throughout the whole day (Rowlands et al., 2007(a))

Figure 2.1.(a) Polar® HR monitor. **(b)**Yamax Digiwalker DW-200®. **(c)** ActiGraph™ GT1M formerly the CSA/MTI. All are small, lightweight, black box designed devises used to objectively assess PA.

HR monitoring relies upon the long established linear relationship between HR and oxygen uptake over a wide range of exercise intensities (Bergen and Christensen, 1950). Although not a direct measure of PA, HR monitoring can indicate the relative stress placed on the cardiovascular system by PA activity (Armstrong et al., 1998) and allows the recording of values over time, giving insight into the pattern and intensity of daily PA (Rowlands et al., 2007(a)). The most commonly used HR devise is the Polar HR monitor (Figure 2.1. (a)) which consists of a wrist mounted monitor and a HR belt. The technique has been validated in children against the doubly labelled water technique, the Gold Standard for measuring energy expenditure, where it is said to provide a close estimation of total energy expenditure and provide and objective assessment of patterns of PA (Livingston et al., 1992). This has led to the widespread use of HR monitoring to assess energy expenditure and thus PA in both adults and children. (Sirard et al., 2001). HR monitors consist of a chest mounted transmitter belt and a small watch sized receiver which can store heart rate information for up to a week. They are unobtrusive in nature and therefore permit free living movement (Armstrong and Welsman, 2006). However, the interpretation of HR data can be complex. A review by Harro and Riddock (2000) identified 24 different methods of possible data reduction and thus makes it hard to compare current data across studies. Although cheap and easy to use, at rest, and during the lower spectrum of PA, the linear relationship between HR and oxygen uptake tends to be affected by external factors such as emotional stress, anxiety, fatigue, body position, active muscle groups, training status, hydration status, food intake and environmental conditions such as ambient temperature and humidity (Armstrong, 1998). The FLEX-HR method has been developed to limit these influences in young people. This technique allows for the calculation of an individually calibrated equation which can be used to distinguish between rest and actual energy expenditure (Livingstone et al., 1992). However, such individual calibration makes the technique ill suited for large epidemiological studies (Rowlands et al., 2007(a)). Another disadvantage is that HR tends to lag behind changes in energy expenditure and therefore in PA. HR tends to remain elevated after the cessation of movement and leads to the masking of sporadic bouts of high intensity physical activity characteristic of childhood activity patterns (Rowlands et al., 2007(a)). Due to the complicated nature of HR analysis and the effect of non-physiological factors, motion sensors have become the objective tool of choice. Pedometers and accelerometers are inexpensive, unobtrusive and can objectively assess physical activity (Sirard et al., 2001)

Pedometers consist of spring suspended lever arms which move with the vertical acceleration of the hip (Tudor-Locke et al., 2004), an example of a commonly used pedometer is the Yamax Digiwalker DW-200® seen below (Figure 2.1. (b)). Such pedometers give an output in either mileage or more commonly steps over a given period of time (Sirad et al., 2001). Pedometry has been validated in children against

HR and oxygen consumption (Eston et al, 1998; Louie et al., 1999) however output is generally from a 24 hour epoch and thus gives no insight into intensity, duration or frequency of PA (Miles, 2007; Corder et al., 2007; Sirard et al., 2001). Additionally, pedometers are unable to measure PA during activities such as cycling and stair climbing, and accuracy is found to be diminished at speeds less that 3km/hr (Melanson et al., 2004) and over 16km/hr (Rowlands et al., 2007(b)). Another issue is that attempts to link pedometry with free living energy expenditure have been, in the main, unsuccessful (Leenders et al., 2001). However, although unable to give accurate information of PA patterns or on EE, pedometers are still widely used due to their cost, ease of use and unobtrusive nature. Their value as a motivational tool to increase PA is also important (Cordon et al, 2007; Sirard et al., 2001).

Accelerometers are portable recording devices able assess the degree of acceleration of the body. In the last few decades their use in scientific studies has increased exponentially (Chen and Bassett, 2005) as they can objectively measure PA giving a comprehensive picture of intensity, frequency, duration and total volume of activity (Strath et al., 2005). Acceleration can be defined as a change in speed with respect to time, where speed is a change in position with respect to time. The unit of acceleration is g, the gravitational acceleration unit where 1g = 9.8m/s. Most accelerometers are piezoelectric accelerometers consisting of a piezoelectric element and a seismic mass in an enclosed space. There are two common configurations; the IC Chip configuration and the Cantilever Beam configuration (Figure 2.2.). When an individual moves, the sensor accelerates causing the seismic mass to shift, resulting in a conformational change to the piezoelectric element. The piezoelectric element either bends the sensor, in the case of the Cantilever Beam formation, or causes the build up of tension or compression, in the case of the IC Chip. The change caused by the movement of the seismic mass causes the build up of charge on one side of the sensor, generating a variable output voltage signal, proportional to the applied acceleration. This is called a count and the larger the movement the larger the counts value. The Cantilever beam configuration is often called a uniaxial accelerometer, measuring accelerations along one plane (Chen & Bassett, 2005).

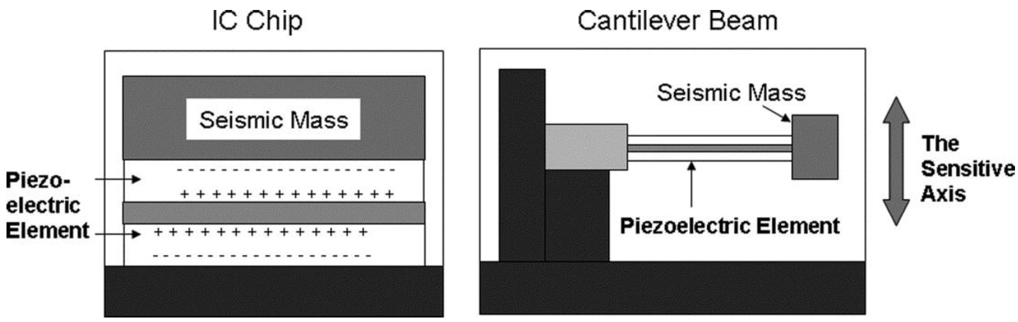

Figure 2.2.Schematic representation of two configurations of accelerometers (Chen & Bassett, 2005)

The most widely validated accelerometer used to objectively assess PA levels is the ActiGraph™ GT1M (Figure 2.1. (c)) formerly the CSA/MTI (Actigraph, LLC, Fort Walton Beach, Florida, USA). This is a uniaxial accelerometer which has been validated for use in children and adolescents (Fairweather et al., 2002; Trost et al., 1998; Reilly et al., 2003(a)). The Actigraph is small, lightweight and designed to measure and record vertical accelerations within a physiological range. The signal is digitalised and the magnitude is summed over a user specific time interval called an epoch. At the end of each epoch the summed value is stored in memory and an output in counts per chosen epoch is given. Unlike pedometers, accelerometers are able to quantify the duration, frequency and intensity of PA (Sirard et al., 2001; Welk et al., 2000; Corder et al., 2007; Rowlands et al., 2007(a)) which allows for insight into the patterns of childhood PA. Of particular interest is the number of minutes of MVPA children take part in allowing comparisons to be drawn with the current paediatric guidelines that suggest children take part in at least 60 min of MVPA per day (Cavill et al., 2001; US Department of Health, 1996).

Groups have compared measured PA levels to these guidelines and found the majority of British children to be meeting them. For example, Riddoch et al. assessed PA objectively using accelerometry in European children and found 97% of 9 year old girls and boys were meeting the current guidelines (Riddoch et al., 2004). However, another study by the same author using similar measurement techniques (Riddoch et al., 2007) found only 5.1% of British boys and 0.4% of British girls aged 11 years old met the current guidelines for PA. Given the current rising trend in obesity levels in British children (Health survey for England 2006, 2008; NHS Quality Improvement Scotland, 2004) other objective methods, such as heart rate monitoring (McKee et al., 2005), pedometry (Cardon et al., 2007) and where acclerometry has been linked to energy expenditure using doubly labelled water (Reilly et al., 2008), have reported MVPA to be low, it is almost certain that the higher percentage of children meeting the current PA guidelines reported in the first study is inaccurate.

Another example is from a study by Trost et al. (2007) used the Actigraph™ to assess the PA levels of children attending after-school programs in a group of 10 year olds. They found children were taking part in roughly 20 min of MVPA per day, two thirds of the current guidelines for PA (Trost et al., 2007). Another study using the same accelerometer in a group of primary school children from Europe looked into the effect of different modes of transport on physical activity levels. This group reported levels of MVPA in the region of 155-193 min per day (Cooper et al., 2005), over three times the current guidelines for MVPA. These examples illustrate the vast range of reported PA levels using accelerometry and present a very confusing picture. The need to standardise across studies is clearly important before conclusions can be drawn on the amount of PA our children are taking part in. Recently the two main issues to be raised in the field of accelerometry are sampling interval or epoch and which set of cut-point to use to classify PA as sedentary, light, moderate and vigorous (Reilly et al., 2008; Rowlands et al., 2007 (a); Trost et al., 2005).

Currently, the majority of accelerometer studies utilise a 60 s epoch for data collection (Hughes et al., 2006; Puyau et al., 2002; Reilly et al., 2003; Treuth et al., 2003) which means that activity over a 60 s period if summed and committed to the device memory. Some researchers have begun to question whether long epochs such as 60 s are appropriate for the assessment of PA in children (Reilly et al., 2008). The limited existing evidence suggests that longer epochs misclassify high activity as being of lower intensity, by averaging with bouts of lower intensity activity and sedentary behaviour within the same epoch (Nilsson et al., 2002; Reilly et al., 2008; Rowlands et al., 2006). Nilsson et al. (2002) assessed PA in a group of 16 children with an average age of 7 and half years. Using a CSA accelerometer, PA was measured over a 4 day period and data was recorded in a 5-second epoch. Data was then reintegrated into 10, 20, 40 and 60 s epoch using the manufactures software and treated with cut-points for moderate, high and very high intensity levels of PA as previously calculated by Freedson (Freedson et al., 1998). Results indicated that for moderate PA, epoch had no effect on time reported engaging in this type of PA, however both high and very high levels were significantly affected by epoch. Smaller epochs, such as 5, 10 and 20, reported significantly more time engaging in high and very high physical activity compared to the larger epochs. Nilsson et al. (20027), therefore came to the conclusion that measuring PA using a longer epoch such as 60 s will mask short periods of high intensity PA which would otherwise be detected if measured using smaller epochs such as 5 s (Nilsson et al., 2007).

Rowlands et al. (2006) came to a similar conclusion in a study which measured the PA levels of 25 7-11 year olds from North Wales using a Tri-axial accelerometer. Each child wore two accelerometers, one set to record at a 1 s epoch and one to record at a 60 s epoch, for at least 6 hours (Rowlands et al., 2006). Data was downloaded and treated with cut-points for low, moderate, vigorous, hard and very hard PA as calculated by Rowlands et al. (2004) in a previous study. It was found that there were no significant difference between the two epochs when reporting light or hard PA however the larger epoch reported significantly more minutes of MVPA and fewer minutes of the very high PA compared to the shorter epoch of 1 s (Rowlands et al., 2006). Reilly et al. (2008) further supports this in a review paper which re-analyses existing accelerometer data from a group of 5-6 year old children originally recorded in a 15 s epoch. Data was reintegrated into a 30, 45 and 60 s epoch and treated with previously determined cut-points for sedentary behaviour and MVPA (Puyau et al., 2002; Reilly et al., 2005). Epoch had no effect on reported sedentary behaviour, but had a statistically significant effect on reported MVPA with the 15 s epoch reporting roughly 28 min of MVPA and the 60 s epoch reporting roughly 18 min of MVPA. Although Reilly et al. (2008) came to the conclusion these differences, while significant, were small, it does illustrate the vast effect epoch can have in reported MVPA.

The effect of epoch is of particular importance when considering the PA patterns in children. An observational study carried out by Bailey et al. (1995) looked at the PA patterns of 15 children aged between 6 and 10 years using a highly detailed observational technique called FATS (Bailey et al., 1995). This technique involved an investigator observing the child over a 4 hour period split up into 30 min blocks. During each block an intensity code was recorded every 3 s. A comprehensive coding system was used, developed by Klesges et al.(1990), which had fourteen categories for postures and three possible intensities corresponding to light, moderate and intense. Investigators were highly trained and coding reliability was determined for all involved (Klesges et al., 1990). A comprehensive picture of PA was therefore created and it was found activities defined as moderate intensity accounted for roughly 20% of children's time, while high intensity activities only accounted for 3% of their time. More importantly, the study gave great insight into the pattern of children's activity and found the mean duration of activity events of low and medium intensity lasted 6 s while the events of high intensity only lasted 3 s. Bailey went on to describe childhood physical activity as 'highly intermittent and sporadic' (Bailey et al., 1995). Additionally a study carried out by Basquet et, al. (2007), used accelerometry to assess PA in 34 French children, and found 96% of very high intensity physical activity lasted less than 10 s further highlighting the highly sporadic and intermittent pattern of childhood physical activity (Basquet et al., 2006). Therefore it may be more appropriate, when objectively assessing PA using accelerometry, to use smaller epochs such as 5 s or even 1 s when MVPA and high intensity physical activity is of interest.

Another factor which may affect the amount of reported sedentary behaviour and physical activity is the use of different cut-points (Reilly et al., 2008; Penpraze et al., 2006; Roberts et al., 2007; Anderson et al., 2005). Cut-points allows for the calculation of the number of minutes spent engaging in sedentary, light, moderate and vigorous physical activity. Of particular interest is moderate and vigorous combined (MVPA) as this is thought to have positive effect on health and body fat (Reilly et al., 2003; Sirard et al., 2001) and can be related to the current guidelines for PA (Cavill et al., 2001; US Department of Health, 1996). Cut-point values have been developed using many different techniques, some relate accelerometer counts directly to energy expenditure (Treuth et al., 2003; Pate et al., 2006), some relate counts to direct observation, while others rely upon energy expenditure prediction equations (Freedson et al., 1997; Trost et al., 2000) often developed for adults and adapted for use with children. In most cases they allow the calculation of the number of minutes spent engaging in sedentary, light, moderate and vigorous PA. However, each study results in a different counts value for each activity level as seen in Table 2.1. which shows three sets of commonly used cut-points. For example, Pate et al (2006) developed cut-points in a group of 3-5 year olds relating energy expenditure to a series of structured and unstructured activities (Pate et al., 2006). An MVPA cut-point value was calculated as 3360 CPM, where by all count values above this were classed as at least moderate. Another study, by Puyau et al. (2002) related energy expenditure to free living activities and calculated MVPA as anything greater than 3200 counts per minute (CPM), another study by Sirard et al. (2002) again came up with a different MVPA value of 3560 CPM. Calibration studies, based on data originally from adults, such as that carried out by Freedson et al. (1997) came up with a much lower cut-point value of 630 CPM. Using such a low MVPA value would lead to reports of much higher numbers of MVPA compared to the other cut-points listed.

Table 2.1. Cut-point values in CPM used to determine sedentary, light moderate and vigorous PA ([1]Sirard et al., 2005; [2]Reilly et al., 2005; [3]Puyau et al., 2002; [4]Pate et al., 2006).

	Sirard[1]	Reilly[2]	Puyau[3]	Pate[4]
Sedentary	<1592	<1100	-	-
Light	>1592 <3560	-	<1100	<1680
Moderate	>3560 <5016	-	>1100 <8200	>1680 <3368
Vigorous	>5016	-	>8200	>3368

A handful of groups have looked into the effect of cut-points on reported PA levels (Reilly et al., 2008; Penpraze et al., 2006; Roberts et al., 2007; Anderson et al., 2005). Penpraze et al. (2006) investigated the effect of three different cut-points on the amount of sedentary behaviour and MVPA reported. Levels of both activities were described as being ‘sensitive’ to choice of cut-point, with all four cut-point values for MVPA (Puyau >3200 CPM, Treuth >3000 CPM and Janz > 615 CPM) leading to reports of significantly different percentages of time spent engaging in MVPA (Penpraze et al., 2006). Additionally Roberts et al. (2007) carried out a similar study comparing four different cut-point values for MVPA and came to the conclusion that data treated with different cut-point values should not be compared (Roberts et al., 2007). This was also illustrated in a study by Anderson et al. (2005) in an American cohort of children where the lower Trost/Freedson et al. (1997) cut-points gave consistently higher values for MVPA compared to the Puyau et al (2002) cut-points (Andersen et al., 2005). More recently, Reilly et al (2008), re-analysed data using three different cut-points for sedentary behaviour and MVPA and found values ranging from 180-501 min of sedentary behaviour and 28-266 min of MVPA, clearly illustrating the effect cut-points have on calculated levels of activity (Reilly et al., 2008). However, the majority of accelerometer studies used to highlight the effect of both accelerometer cut-point and epoch have been in studies on European and American populations, renowned for their low levels of physical activity (Reilly et al. 2005; Trost et al. 2007). The effect of epoch in PA has been demonstrated to be more important in the high end of the PA spectrum in European populations (Rowlands et al., 2006; Nilsson et al., 2002) so therefore would become even more important in a highly active population of individuals.

East African populations are thought to lead a far more active lifestyle than their Western counterparts, in the main due to their active lifestyles which includes running or walking to school (Saltin et al., 1995 and 1996; Scott et al., 2003; Onywera et al., 2006) and chores such as fetching water and wood, cattle herding and field work (Larsen et al., 2004) (See Figure 2.3. (a), (b), (c) and (d)). Although precise data on PA levels of Kenyan children does not exist, a study by Larsen et al. (2004) assessed PA levels by questionnaire in the Nandi region of Kenya and reported that Nandi boys aged 4-12 years either walked or ran significant distances to school each day. Boys took part in chores such as cattle herding, field work, washing clothes, shopping and fetching water, all of which involved travelling long distances on foot (Larsen et al., 2004). Additionally, Onywera et al. (2006) found that in a group of roughly 90 students, that 80% of individuals either ran or walked to school as children, which is considerably more than reports from Western populations, where only 10% of American children were found to walk to school (Cooper et al, 2005). Larsen et al. (2004) also found Kenyan children to have a lower body mass index (BMI) compared to children from Western countries and could reflect, in part at least, the active African way of life (Larsen et al., 2004).


(a)


(b)


(c)


(d)

Figure 2.3.(a) Depicts the active past times Kenyan children take part in. **(b)** Shows children taking part in active play during the school day. **(c)** Kenyan school children walking into school. **(d)** A rural house in Kenya which has no mains electricity or running water.

3. Aims

Therefore, the main aims of the present study are,

1. Give some insight into the sedentary behaviour and PA levels of a small sample of Kenyan School children.

2. Investigate the effect of epoch on the assessment of sedentary behaviour and PA in a highly active population of Kenyan school children.

3. Investigate the effect of using different pre-determined cut-points on the assessment of sedentary behaviour and PA in this population sample.

4. Material and Methods

Subjects: 26 children aged between 4 and 16 years were recruited from both rural (n=15; 5 girls) and urban (n=12; 5 girls) schools in the Nandi region of Kenya. Demographic information can be viewed in Table 5.1. Children classified as urban lived within the municipal boundaries of Eldoret town which is the fifth largest urban centre in Kenya (Figure 4.1.). Those classified as rural were from small villages situated at a radius of about 30-35 km outside the municipal boundaries of Eldoret town. The majority of these small villages had no electricity or main line water therefore members of the community, and in particular children, spend much of their time engaged in active pastimes (e.g. fetching water from streams/rivers, collecting firewood from forests and running to school). Children from both areas were chosen to represent a small cross section of the Kenyan population. Informed written consent was obtained from parents and the principals of the participating schools in Eldoret Town Council (urban group) and Wareng County Council (rural group). Children were approached during school and asked to gain written permission from parents. Where it was not possible for written permission to be granted, a native speaking investigator approached the families to gain consent. Ethical approval for the study was granted by the Institutional Research Ethics Committee (IREC), Moi University, Eldoret, Kenya (Appendix 1).

On the first day of testing, children were invited to come for an examination where height was measured to the nearest 0.1 cm using a portable stadiometer (Somatometre', France) and weight to the nearest 0.1 kg using portable scales (Seca, Vogel & Halke Hamburg, Model 761) for all children. Measurements were repeated twice to ensure accuracy and an average taken. If the two measurements varied by more that 10% then a third measurement was taken. Height and weight data was then used to calculate mean body mass index (BMI = weight in kilograms/height in meters squared) and standard deviation scores (SDS) for BMI using Child Growth Foundation Software (Child Growth Foundation, London, UK: Table 1.) were calculated back in the lab in Glasgow using a specially designed formula.

Physical Activity: Free living habitual PA levels were objectively assessed using the ActiGraph^{TM} GT1M formerly the CSA/MTI (Actigraph, LLC, Fort Walton Beach, Florida, USA) (Figure 2.1. (c)) uniaxial accelerometer which has previously been validated for use in children and adolescents (Fairweather et al., 1999; Reilly et al., 2003; Trost et al., 1998). The Actigraph is small (3.8 x 3.7 x 1.8 cm), lightweight (27g) and designed to measure and record vertical accelerations within a physiological range of 0.05 to 2.00 g with a frequency response of 0.25 to 2.50 Hz. Any acceleration out with this range is filtered to prevent the inclusion of non-physiological tasks, such as riding in a car or operating machinery. The signal is then digitalised and the magnitude is summed over a user specific time interval called an epoch. At the end of each epoch the summed value is stored in memory and an output in counts per chosen epoch is given. The Actigraph accelerometer can be set to record PA in a range of epochs from 1 s to 60 s; on the occasion it was set to record in a 1 s epoch to enable further analysis into the effect of epoch back in Glasgow. This is done by plugging the accelerometer into a USB and accessing the manufacturer's software which talks you through setting up the accelerometer, asking for the subject's name, which epoch you wish to record in and when you wish the accelerometer to begin recording. Additionally, the manufactures software carried out an auto calibration to ensure the accelerometer is still responding to the desired range of accelerations. Children wore the accelerometer for three consecutive school days, between July and August 2007 which represents the wet winter period in Kenya. Accelerometers had to be fully charged to allow three days of data to be recorded. This was achieved by plugging the accelerometer into the USB and leaving over night, giving enough battery power for three consecutive days of recording. However, the restricted capacity of the accelerometers memory is such that it cannot store accelerometer data recorded in a 1 s epoch for more than 24 hours therefore, the accelerometer had to be downloaded every day to clear the memory. Accelerometers were distributed to children early in the morning of day one and height and weight were measured as described above. Once initialised, accelerometers were placed in a protective pouch attached to an elastic belt and placed on the right hip of each child and adjusted to ensure close contact with the body. Each child was shown how to put the accelerometer on and instructed to wear it under their clothes. Additionally, they were instructed to wear the accelerometer at all times except when bathing, swimming and sleeping. Accelerometers were removed for a brief period every 24 hours for downloading of data due to a restrictive memory capacity as described above. In order to carry out this essential downloading process, children were visited by an investigator again on the morning of day two, three and four, and data downloaded on to a laptop computer using the manufacturers software. This gave a raw file called a .dat file for each day which was deleted daily when downloaded allowing the accelerometer to be reset for the next day.

Figure 4.1. Map of Kenya showing the situation of Eldoret close to the Rift Valley.

Once back in Glasgow, each child had 3 .dat files corresponding to each day of recording. Each .dat day file was converted into an excel file using a specially designed macro supplied by Actigraph™. This was required as the current Actigraph software does not allow a full 24 hour period recorded in a 1 s epoch to be viewed in excel. Each excel file was then reintegrated from a 1 sec epoch into 5, 15, 30, 45 and 60 s epochs using a specially designed excel formula. This formula summed all activity counts from the required time frame to give an output in the required epoch. For example, for a 5 s epoch, 1 s activity counts were summed every 5 s to give a single activity count for the given 5 s interval throughout the entire file. This was repeated for all epoch from 5 – 60 s. Data was then edited manually, removing periods corresponding to sleep and times when the monitor was removed as identified from the PA diary (Appendix 2). Additionally, periods of 20 min or longer of consecutive zero counts were removed prior to further analysis as recommended by Treuth et al (2003) who previously found that a period of 20 min or more consecutive zero counts was not observed in awake children (Treuth et al., 2003). This required each file to be edited manually by eye taking several hours per file. Subjects were excluded at this stage if they did not have three days of data collection containing 6 hours or more of PA data. These criteria have previously been shown to be sufficient to represent habitual PA in children (Trost et al., 2000). This resulted in the exclusion of 5 subjects who all only has two full days of monitoring. Although the children said they had worn the accelerometers for three days, from the output it was clear they has not. Further information on habitual PA was gained from a PA diary completed by the child or their parents (Appendix 2). The diary was explained by a native language speaker and detailed time to wake and sleep, mode of transport to school, time spent travelling to school and leisure time activities.

Total monitoring time and average counts per minute (CPM) were calculated in excel (Table 5.1.). All the manually edited data was then treated with previously published cut-points (Pate et al., 2006; Puyau et al., 2002; Reilly et al., 2003; Sirard et al., 2005; Table 2.1.) to determine time spent engaging in PA levels corresponding to sedentary, light, moderate and vigorous intensities. This was achieved by applying another excel formula to all of the reintegrated files which calculated how many cells exceeded the cut-point values for all three sets of cut-points (Table 2.1.). The cut-points used can be seen in Table 2.1 and were created by Pate et al. (2006), Sirard et al. (2005), Reilly et al (2003) and Puyau et al. (2002). Pate et al. (2006) created cut-points for children aged 3-5 years and were developed using accelerometer data recorded in a 15 s epoch, although data is shown in Table 2.1. as CPM to allow comparisons to be drawn (Pate et al., 2006). Cut-points were developed from structured activities and then cross validated with unstructured activities. They allow for the calculation of time spent engaging in light (<420 counts/15 s), moderate (>420 counts/15 s, <842 counts/15 s) and vigorous PA (>842 counts/15 s) (See Table 2 for CPM values). Sirard et al.,

(2005) developed cut-points in a population of preschool children aged 3-5 years using data recorded in a 15 s epoch and gave cut-point values for time spent engaging in sedentary (<398 counts/15 s), light (>398 and <890 counts/15 s), moderate (>890 and <1254 counst/15 s) and vigorous PA (>1254 counts/15 s) (For CPM values see Table 2.1). The third set of cut-points are a combination of two previous studies by Reilly et al., (2003) and Puyau et al. (2002), both developed from accelerometer data recorded in a 60 s epoch. The Reilly et al. (2003) and Puyau et al, (2002) cut-points were developed in a population aged 3-6 years and give a value for sedentary (<1100 CPM), light (<3200 CPM), moderate (>3200 and <8200 CPM) and vigorous PA (>8200 CPM) (see Table 2.1 for CPM values). Cut-point values were either divided down or multiplied up for data reintegrated into 1, 5, 15, 30, 45 and 60 s epochs and incorporated in the formula to calculate time spent engaging in PA levels for each epoch.

Data analysis: Data were expressed as the mean ± s.d. following a test for the normality of distribution. Statistical analysis was carried out using a three-way analysis of variance (ANOVA) to determine if both epoch and cut-point had a significant overall effect on the number of reported minutes if sedentary behaviour and PA followed by a simple main effects analysis for two way interactions. Once significance was established a one-way ANOVA with Tukey's pairwise comparisons was used to determine the differences between measured sedentary behaviour and PA levels across all epochs and cut-points. Significance was set to $P \leq 0.05$. Differences in CPM and total monitoring time across all epochs were tested using a simple 1 way ANOVA with Tukey's Pairwise Comparisons. BMI SDS scores were calculated using Child Growth Foundation Software (Child Growth Foundation, London, UK: Table 1.)

5. Results

Analysis of the PA diaries/questionnaires revealed that 52% of children walked, and an equal distribution ran and traveled by car to school with the majority of children travelling in total to and from school less than 30 min. Only two subjects travelled longer than 30 min with one subject spending over 60 min travelling to and from school on foot. All 21 subjects reported that they were involved in household chores and leisure time was spent doing active PA such as running, jumping, and skipping and passive activities such as study or watching television. For the rural subjects, chores also involved cattle herding, fetching of water from streams and rivers and gardening (Table 5.1.). On average a BMI SD score of -0.52 was calculated for the population (Table 5.1.). Of the 21 subjects, 3 were classed as overweight (SD scored equal to or greater than 1.04, equivalent to the 85th percentile of the UK reference population in 1990 (Cole et al., 1995)) and 1 was classed as obese (SD score greater than 1.64, equivalent to 95th percentile, Cole, 1995).

Sedentary: The amount of time classified as sedentary was not affected by choice of epoch (Table 5.2, For Reilly et al. (2003) cut-point, P=0.919, for Sirard et al. (2005) cut-points, P=1.000), nor the choice of cut-point on the number of minutes of reported sedentary behaviour across all epochs (Table 5.2; P>0.05). The amount of time spent engaging in sedentary activity was approximately 10 hrs (equivalent to 82% of awake time) as calculated with the Sirard et al. (2005) and Reilly et al. (2003) cut-points. There was a small but non-significant reduction in time spent engaging in sedentary activity as epoch increased from 1 to 60 s using the Reilly cut-points, with a 1 s epoch reporting 26 min more sedentary behavior compared to a 60 s epoch (Table 5.2; P=0.919).

Light, moderate, and vigorous PA: In contrast to sedentary behavior, duration spent in light, moderate, vigorous and MVPA was significantly influenced by the choice of cut-point and epoch (Table 5.2.; Figures 5.1.-5.12.).

The use of the Pate et al. (2006) cut-points resulted in reports of over ten times more minutes of light PA compared to the Sirard et al. (2005) and Puyau et al (2002) cut-points across all epochs (Table 5.2., Figure 5.1, 5.2 and 5.3; P=0.00). The Puyau et al. (2002) cut-points resulted in significantly more minutes of light PA compared to the Sirard et al (2005) cut-points in a 5 s epoch only (Table 5.2., Figures 5.1. and 5.2.; P=0.024), reporting roughly twice the amount of light PA compared to that expressed using the Sirard et al. (2005) cut-points at this epoch only. Epoch also had an effect on reports of light PA calculated using the Sirard et al. (2005) and Puyau et al. (2002) cut-points. Smaller epochs such as 1 s reporting 32 min more light PA when using the Sirard et al. (2005) cut-point and 53 min more when using the Puyau et al. (2002) cut-points compared to a 60 s epoch (Table 5.2., Figure 5.1. and 5.2.; P=0.00). Epoch had no effect on the number of light minutes as expressed with the Pate cut-points with values ranging from 596 min in a 1 s epoch to 604 min in a 60 s epoch (Table 5.2., Figure 5.3.; P=0.00).

For moderate PA, the Puyau et al. (2002) and Pate et al. (2006) cut-points consistently reported significantly more minutes compared to the Sirard et al. (2005) cut-points in all epochs (Table 5.2., Figures 5.4., 5.5. and 5.6.; P=0.00) in contrast to light PA

(Table 5.2., Figure 5.1., 5.2. and 5.3), reporting roughly 100% more minutes of this type of activity at all epochs. Additionally, the Pate et al. (2006) cut-points reported significantly more minutes of moderate PA (Table 5.2., P=0.00) compared to the two other cut-points across all epochs except at 1 and 5 s, where the Pate cut-point reported significantly more moderate PA compared to the Sirard et al. (2005) cut-point only (Table 5.2., for 1 s P=0.310 and 5 s P=0.869; Figure 5.4., 5.5. and 5.6.). Longer epochs such as such as 30, 45 and 60 s led to more moderate minutes of PA when applying the Pate et al (2006) cut-points, with the number of minutes of activity increasing from 52±13 min in a 1 s epoch to 69±20, 69±20 and 70±20 min in a 30, 45 and 60 s epoch (Table 5.2., Figure 5.6.; P=0.007). Only a 1 s epoch led to reports of more minutes of moderate PA when applying the Puyau et al. (2002) cut-points (Table 5.3., Figure 5.5.; P=0.038) reporting 18 min more of this type of activity when expressed in a 60 s epoch. Choice of epoch had no effect on the amount of moderate PA classified using the Sirard et al. (2005) cut-points (Table 5.2, Figure 5.4; P=0.061), although a non-significant decline in the number of minutes of this type of activity was seen when moving from a 1 to 60 s epoch.

For vigorous PA, the use of the Pate et al. (2006) cut-points reported significantly more minutes compared to the Puyau et al. (2002) cut-points at all epochs and the Sirard et al. (2005) cut-point at epochs greater than 5 s (Table 5.2., Figure 5.10., 5.11. and 5.12.; $P<0.05$). The use of the Sirard et al. (2005) cut-points resulted in significantly more minutes of vigorous PA compared to the Puyau et al. (2002) cut-points at epoch 1, 5, 15 and 30 s (Table 5.2., Figure 5.7. and 5.8.; $P<0.05$) but not at the longer epochs (Table 5.2., Figure 5.7. and 5.8.; $P>0.05$). For all cut-points, shorter epochs report significantly more minutes of vigorous PA compared to longer epochs

(Table 5.2., Figure 5.7., 5.8. and 5.9.; P<0.05). The Sirard et al. (2005) saw the number of minutes of vigorous activity as calculated as a percentage of the daily sedentary behaviour and PA, decline from roughly 6% of daily activity when reported in a 1 s epoch to roughly 1% in a 60 s epoch, for the Puyau et al (2002) this declined from roughly 1% of daily activity to no vigorous activity in a 60 s epoch and for the Pate et al. (2006) from 8% in a 1 s epoch to 5% in a 60 s epoch.

The amount of time engaging in MVPA, as derived using the Pate et al. (2006) cut-points, was significantly greater compared to both the Sirard et al. (2005) and Puyau et al. (2002) cut-points across all epochs (Table 5.2., Figure 5.10., 5.11. and 5.12.; P<0.05) with the Pate et al. (2006) cut-points reporting 95% individuals taking part in the daily recommendation for MVPA across all epochs compared to roughly 20% as calculated with the Puyau et al (2002) cut-points ranging from 57-10% when expressed with the Sirard et al. (2005) cut-points across all epochs (Table 5.2.). There was no difference in the amount of time engaged in MVPA between the Sirard et al. (2005) and Puyau et al. (2002) cut-points, although there was considerable variability across epochs (Table 5.2., Figure 5.10. and 5.11.). Epoch had no effect on the amount of MVPA as reported by the Pate et al. (2006) cut-points (Table 5.2., Figure 5.12., P=0.968) however, for the Sirard et al. (2005) cut-point there was a significant decline in the amount of time spent engaging in MVPA when comparing a 1 and 5s epochs to all others (Table 5.2., Figure 5.10.) with the percentage of individuals attaining the guidelines declining from 57 % in a 1 s epoch to only 10% in a 60 s epoch. Additionally when comparing a 1 and 60 s epoch, as calculated with the Puyau et al. (2002) cut-points, the same is true (Table 5.2., Figure 5.11.) with the percentage of individuals achieving the guidelines decreasing from 38% to only 19%..

Table 5.1. Descriptive characteristics Kenyan children expressed as mean ± SD where appropriate (*N*=21).

Age (yr)	10.8 ± 3.7
Gender (Male/Female)	11/10
Weight (kg)	36 ± 13.9
Height (cm)	143.7 ± 30.3
BMI (kg/m^2)	17.3 ± 3.6
BMI (SDS)	-0.52 ± 1.84
Residence (Urban/Rural)	9/12
Monitoring time (min)	693.6 ± 1.8
Activity counts (CPM)	733.4 ± 212.0
Mode of Transport (walk/run/car)	11/5/5
Time to school(<30,>30<60, >60 min)	19/1/1
ADL(passive/active/household)	9/15/15

Table 5.2. Number of minutes of sedentary behaviour, light, moderate and vigorous PA (For Cut-point values see TABLE 2.) plus calculated MVPA across all epochs. In bracket the percentage of the day spent engaging in sedentary activities. For MVPA number in brackets is the percentage of children meeting the current guidelines for 60 min MVPA per day (Cavill et al., 1997). For epoch ♦ indicates a significant difference to a 1 s epoch and ◊ to a 5 s epoch. For cut-points * indicates a significant difference to the Pate cut-point, # to the Puyau cut-point and ~ to the Sirard cut-point (P≤0.05).

Sedentary	1 s	5 s	15 s	30 s	45 s	60 s
Sirard	590± 87(84%)	592±87(84%)	594±88(84%)	596± 89(85%)	598± 90(85%)	598± 94(85%)
Reilly	573 ± 86(82%)	567±87(80%)	554± 85(79%)	554± 88(79%)	550±86(78%)	547± 89(77%)
Pate	Na	Na	Na	Na	Na	Na
Light						
Sirard	38±11*	43± 12#*	76±22♦◊*	79±23♦◊*	81± 24♦◊*	81± 23♦◊*
Puyau	70± 20*	87± 27~*	104 ± 35♦*	111± 38♦*	120±43♦◊*	123± 42♦◊*
Pate	596± 87~#	595± 87~#	595±87~#	597± 88~#	601± 90~#	604± 94~#
Moderate						
Sirard	26± 8#*	29± 8#*	23± 12#*	21± 13#*	20± 13#*	18± 14#*
Puyau	59± 22~	56± 23~	48± 24~*	42± 25~*	49± 27~*	36± 28♦~*
Pate	52± 13~	58± 16~	66± 20~#	69± 20♦~#	69± 20♦~#	70± 20♦~#
Vigorous						
Sirard	47± 19#	42± 20#	16± 14♦◊#*	14± 13♦◊#*	12± 13♦◊*	9± 12♦◊*
Puyau	8±5~*	5±5~*	3±4♦~*	1±3♦~*	2±4♦◊*	0±1♦◊*
Pate	56± 22#	51± 22#	44± 24~#	40± 25~#	37±26~#	32± 26~#
MVPA						
Sirard	73±25(57%)*	71±26(48%)*	37±23(14%)♦◊*	35±24(14%)♦◊*	32±24(14%)♦◊*	28± 24(10%)♦◊*
Puyau	59±22(38%)*	52± 23(29%)*	45±24(24%)*	41± 25(24%)*	38±26(24%)*	36±28(19%)♦*
Pate	108±29(95%)	107±40(95%)	110 ± 31(95%)	109± 32(95%)	106±33(95%)	102±34(95%)

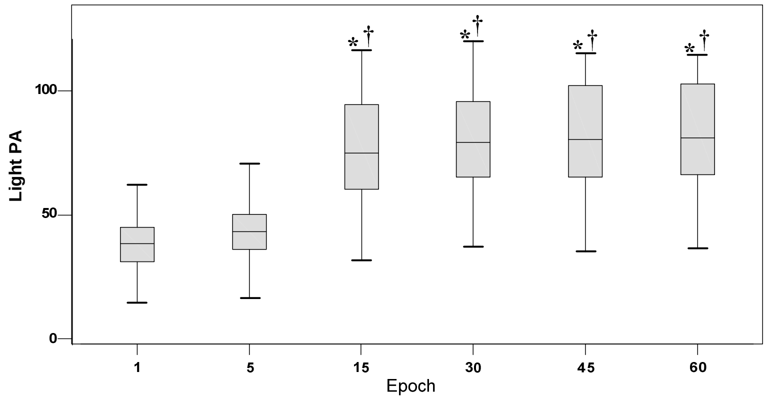

Figure 5.1. Minutes of light PA calculated using the Sirard cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch and †indicating a significant difference a 5 s epoch (P=0.00).

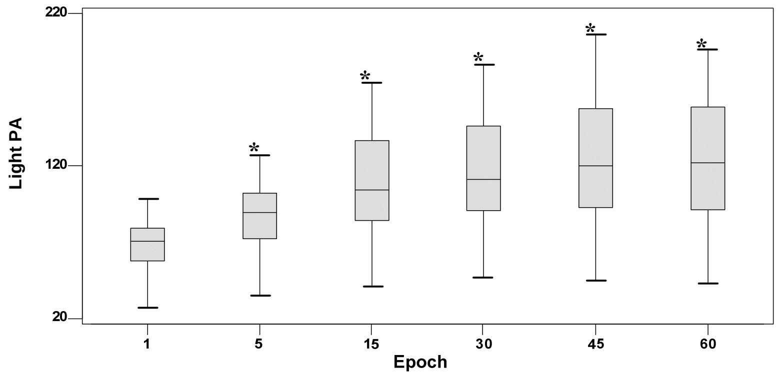

Figure 5.2. Minutes of light PA calculated using the Puyau cut-point (Table 2), across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch (P=0.00).

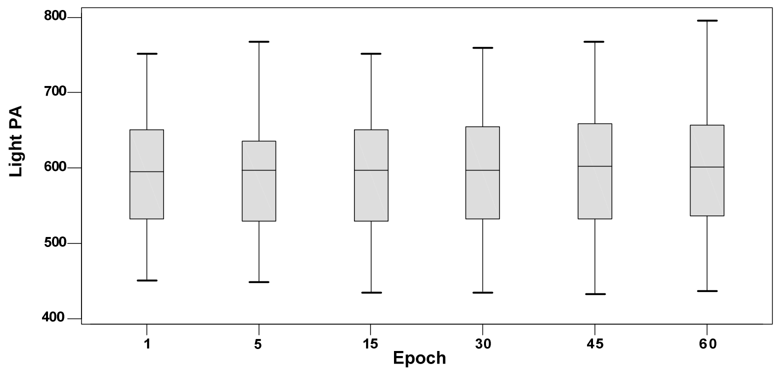

Figure 5.3. Pate Light Minutes of light PA calculated using the Pate cut-point (Table 2) across all 6 epochs for 21 Kenyan children. No significant differences exist (P=0.999).

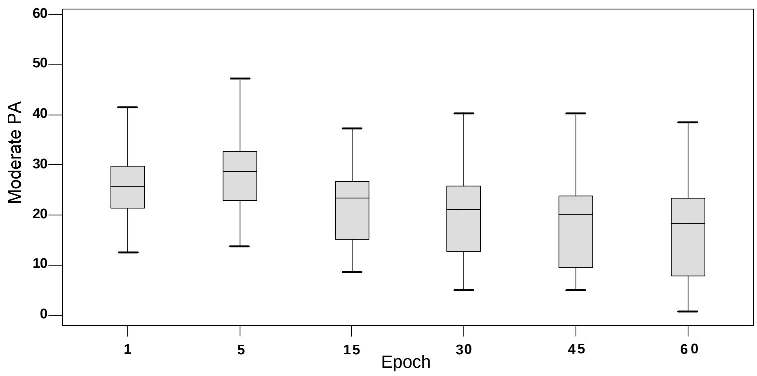

Figure 5.4. Minutes of moderate PA calculated using the Sirard cut-point (Table 2) across all 6 epochs for 21 Kenyan children with no significant differences exist (P=0.061).

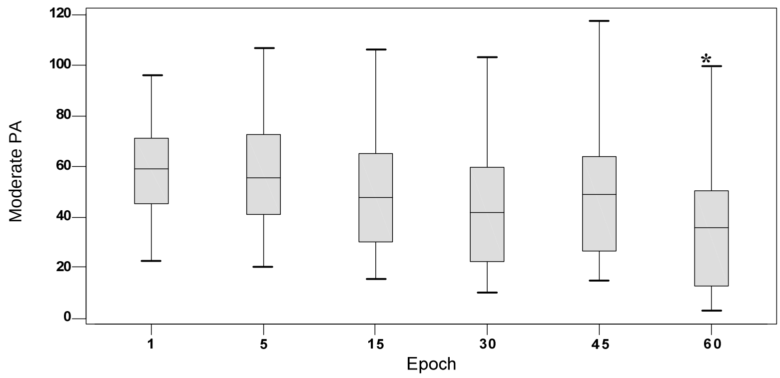

Figure 5.5. Minutes of moderate PA calculated using the Puyau cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch (P=0.038).

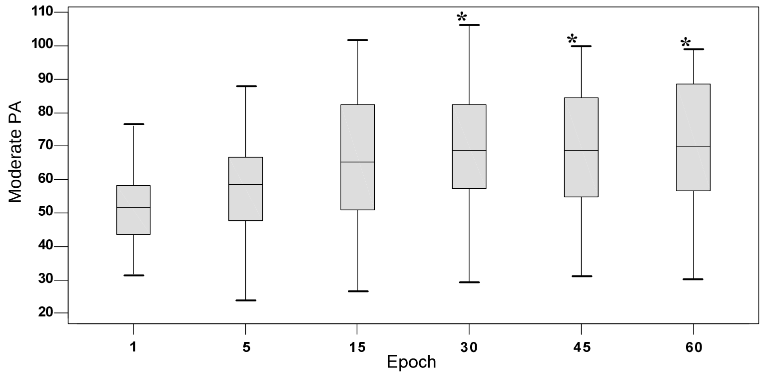

Figure 5.6. Minutes of moderate PA calculated using the Pate cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch (P=0.007)

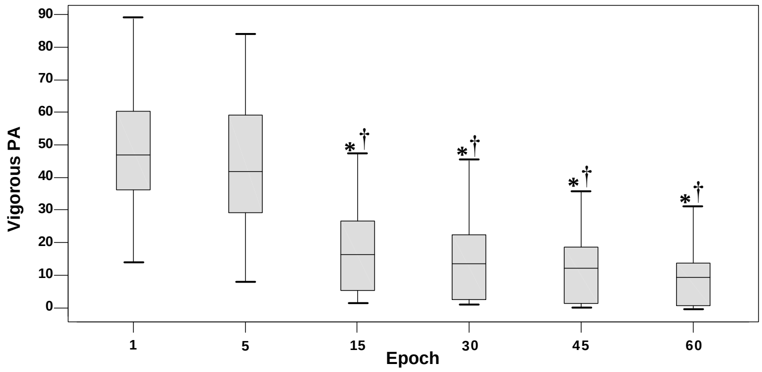

Figure 5.7 Minutes of vigorous PA calculated using the Sirard cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch and †indicating a significant difference a 5 s epoch (P=0.00).

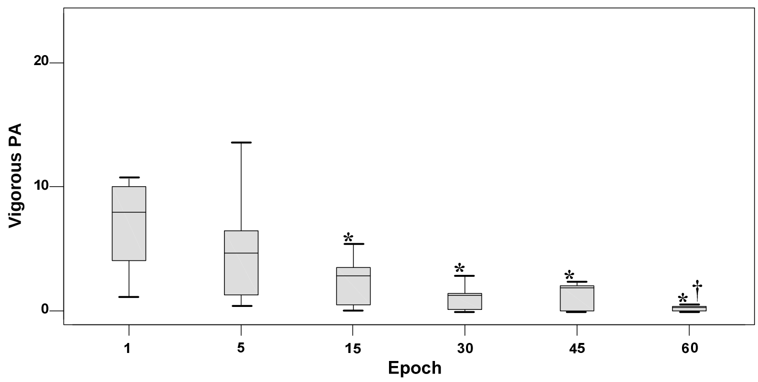

Figure 5.8. Minutes of vigorous PA calculated using the Puyau cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch and †indicating a significant difference a 5 s epoch (P=0.00).

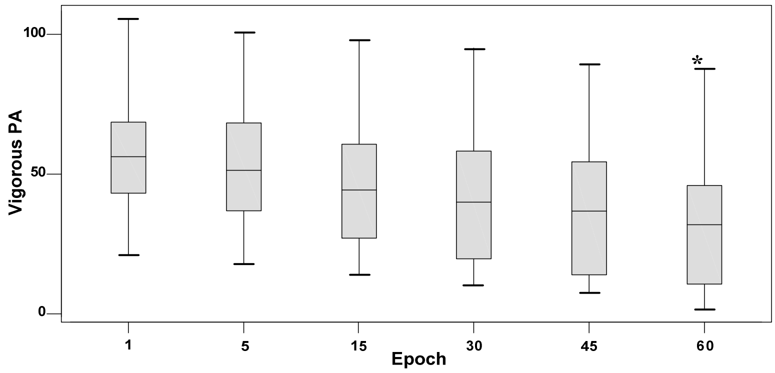

Figure 5.9. Minutes of vigorous PA calculated using the Pate cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s (P=0.013).

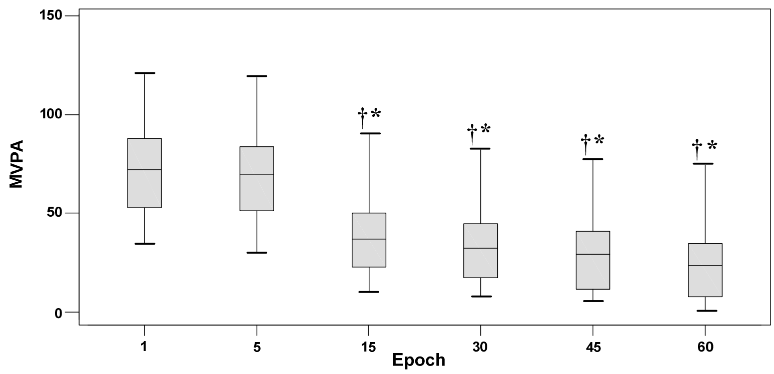

Figure 5.10. Minutes of MVPA calculated using the Sirard cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch and †indicating a significant difference a 5 s epoch (P=0.00).

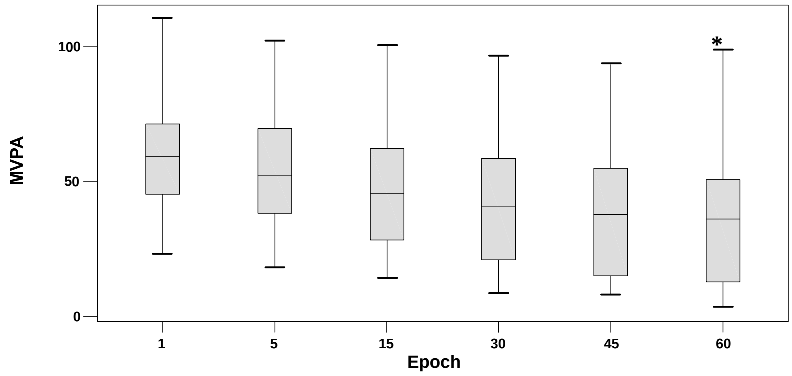

Figure 5.11. Minutes of MVPA calculated using the Puyau cut-point (Table 2) across all 6 epochs for 21 Kenyan children with * indicating a significant difference to a 1 s epoch (P=0.021).

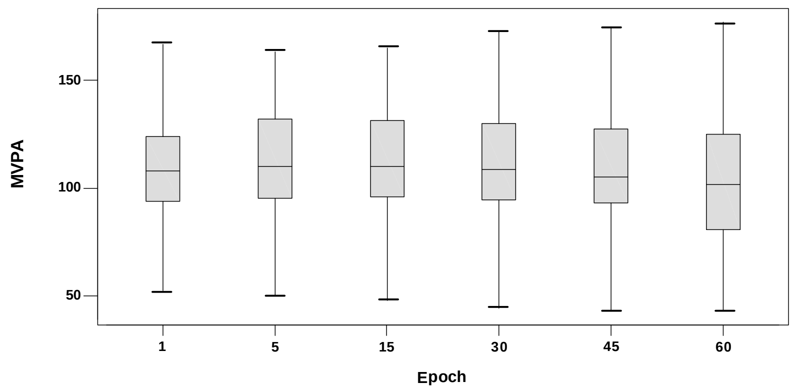

Figure 5.12. Minutes of MVPA calculated using the Pate cut-point (Table 2) across all 6 epochs for 21 Kenyan children no significant differences exists (P=0.968).

6. Discussion

The current study illustrates the significant effect both epoch and cut-points have on reported PA levels in a highly active population of Kenyan children. Longer epochs such as 45 and 60 s underestimate higher levels of PA and overestimate light and moderate PA compared to shorter epochs such as 1 and 5 s, while epoch has no effect on reports of sedentary behaviour. The choice of cut-point also impacts on light, moderate and vigorous PA levels but not sedentary behaviour. The lower the CPM cut-point value the higher the reported PA activity levels.

This is the first study to objectively assess PA levels in a population of Kenyan school children using accelerometry (Table 5.2., Figures 5.1.-5.12.). On average, children in the current study engaged in approximately 36 min of MVPA per day when calculated using the Puyau et al. (2002) cut-point in a 60 s epoch, which equates to 5% of their daily PA, with 19% of the children reaching the current guidelines for PA (Table 5.2., Figure 5.3.) The questionnaire data (Table 5.1.) is in agreement with this, reporting the majority of children spending at least 30 min per day either walking or running to and from school. When comparing this to western populations, western children are spending between 18-20 min per day engaging in MVPA (Reilly et al., 2005; Trost et al., 2007), and only 2.5% of children reach the current guidelines for PA (Riddoch et al., 2007), it is clear the population under investigation here is in fact highly active when assessed objectively with accelerometry. This is in agreement with two previously published studies which reported the highly active nature of East African life (Larsen et al., 2004; Onywera et al., 2006). Larsen et al. (2004) reported that children were walking, on average, 3 hours per day and spending up to 40 min per day working in the field while Onywera et al. (2006) found the majority of elite Kenyan athletes were running or walking distances of up to 10km to school each day as children. However, although compared to western populations this sample of the Kenyan population seem to be highly active, most fail to meet the current guidelines for PA across all epochs (Table 5.1.). It is clear from the questionnaire data, a higher percentage of individuals should be meeting the guidelines but accelerometry fails to report this. This could suggest the Actigraph accelerometer is failing to pick up all high level PA as it has previously only been validated in Western populations (Fairweather et al., 1999; Reilly et al., 2003; Trost et al., 1998) and has never been used in such highly active individuals. More likely is that the set of cut-points used are unsuitable for the population under investigation and do not reflect the activities this population are taking part in. However, no strong conclusions can be drawn about the Kenyan population as a whole, as the study group only consisted of 21 individuals. Further studies on larger groups of Kenyan children are required before any conclusions can be drawn on PA levels of the Kenyan population as a whole. A monitoring period of 3 days was chosen as this had been previously shown to represent habitual PA (Trost et al. 2000). However, Trost et al. (2000) found this gave a reliability of only 0.70 when assessing habitual PA for children aged 5-10 years old (Grades 1-6). For older children a period of 4 to 5 days of monitoring is required to gain the same reliability and, as almost half of the children in this study are over the age of 10, a longer period of monitoring time may be required to gain a true representation of habitual PA. However, Trost et al (2000) carried out their study on western populations who tend to become more sedentary as age increases into early adolescents (Trost et al. 2000), Kenyan children however, do not show this pattern and in fact tend to take part in more PA running further distances to school and taking part in more structured sports activities (Laren et al. 2004). Therefore using a 3 day monitoring period may not impact on reports of PA. Addionally, it would be hard to record for any longer length of time, as the memory constraints of the accelerometer meant that data had to be downloaded every 24 hours. However, since carrying out the study, Actigraph have developed a tri-axial accelerometer, the GT3X Advanced Activity Monitor. This accelerometer has a 4GB memory and a 20 day battery life and is therefore capable of continually recording PA for more than 24 hours thus making it easier to gain 3 days or more of data in rural Kenya. Additionally, we did not ensure monitoring time included a weekend day, which has been demonstrated by Trost et al. (2000) to contain more minutes of MVPA compared to weekdays. This may again lead to underestimations of MVPA, and should perhaps be considered if larger numbers of individuals are to be investigated in the future. Accelerometry is also unable to assess PA such as cycling, stair climbing and swimming (Sirard et al., 2001;Trost et al., 2007), again leading to underestimations of PA levels. However, the nature of Kenyan life, and information gained from the PA questionnaire (Table 5.1.), would suggest that the children in this study do not take part in such activities, spending the majority of time walking, running and playing. Therefore the fact accelerometry is unable to assess such PA would not affect the PA as measured in this population.

The calculated BMI of the group was on average 17.3 kg/m^2 (Table 5.1.), which was lower than that found in a study by Larsen et al. (2004) investigating Nandi school children. This group reported a BMI of 18.5 kg/m^2. Larsen et al. (2004) also carried out comparisons with other groups and came to the conclusion that the Nandi boys had a lower BMI compared to all other western populations, which also seems to be the case with the children in the current study. The mean SD score of -0.52 (Table 5.1.) suggest the population under investigation has a lower BMI, on average, compared to UK children, as calculated using the 1990 BMI reference curves (Cole et al. 1995). As expected, a spread of scores was found with 3 individuals being classed as overweight with an SD score of greater than 1.04. However, the calculation of BMI SD scores as created using 1990 UK reference curves (Cole et al., 1995) which may not be appropriate for a Kenyan population. The curves were developed for British children, and should therefore only be used as descriptive data in order to allow a comparison to be drawn.

For sedentary activities, epoch and cut-point did not have a significant effect on the number of minutes spent engaging in this type of activity (Table 5.2.). This is in agreement with a previous study which reanalysed accelerometry data recorded in a 15 s epoch collected from 32 Scottish children aged 5 and 6 years (Reilly et al., 2008). In agreement with the present study, no significant differences were found in the amount of time spent engaging in sedentary behaviour across all epochs. Furthermore, Reilly et al. (2008) reported approximately 501 min of sedentary behaviour per day, which is somewhat lower than the Kenyan cohort, who spent 547 min engaging in sedentary behaviour (Table 5.2.). This suggests that our study group is at least as sedentary as Western populations. In another cohort of Scottish children it was found that children spent 80% of their time engaging in sedentary behaviour (Hughes et al. 2006), similar to that observed in the Kenyan population who spent somewhere between 77% and 85 of their time engaging in sedentary behaviour depending upon the cut-point and epoch used (Table 5.2). Therefore, the Kenyan children in this study spend a similar amount of time engaging in sedentary behaviour compared to Western populations; although this could be due to differences in the editing process and the presence of low study numbers.

Smaller epochs led to significantly less reported minutes of light PA as calculated using the Sirard et al. (2005) and Puyau et al. (2002) cut-points, but had no effect on the amount as expressed with the Pate et al. (2006) cut-point (Table 5.2.; Figures 5.1., 5.2. and 5.3.). This conflicting picture can be explained by the cut-point value itself (Table 2.1.). For light activity, the CPM value for the Sirard et al. (2005) and Puyau et al. (2002) cut-points are approximately three times higher than the Pate et al. (2006) cut-point (Table 2.1.). This leads to behaviour which may be classified as sedentary by the Sirard et al. (2005) and Puyau et al. (2002) cut-points, being reported as light by the Pate et al. (2006) cut-points, and clearly highlights the effect different cut-points can have on reported PA levels. For moderate and vigorous PA, the effect of cut-point and epoch varied (Table 5.2, Figure 5.4., 5.5., 5.6., 5.7., 5.8. and 5.9.). However, generally epoch appears to have a more pronounced effect on higher intensity PA (vigorous) as opposed to moderate intensity PA, where significant differences where only found between a 1 and 60 s epoch (Table 5.2; Figure 5.4., 5.5., 5.6., 5.7., 5.8., and 5.9.). For example, when expressed using the Sirard et al. (2005) cut-point value, vigorous PA was calculated as 47 min in a 1 s epoch and only 9 min in a 60 s epoch (Table 5.2., Figure 5.7.) while moderate PA ranged from only 26 min to 18 min (Table 5.2., Figure 5.7., 5.8. and 5.9.). For the Puyau et al. (2002) cut-point a 60 s epoch reported no vigorous PA, while a 1 s epoch reported 8 min (Table 5.2., Figure 5.8.), while moderate varied less (59 vs. 36 min) (Table 5.2., Figure 5.4., 5.5. and 5.6.). This is in agreement with a study by Rowlands et al. (2006) who reported epoch had little effect on low and moderate PA, and a significant effect on reported high and very high activity. Additionally, the two lower CPM cut-points thresholds created by Pate et al. (2006) and Sirard et al. (2005) (Table 2.1) led to more reported minutes of vigorous PA, compared to the Puyau et al. (2002) cut-point at all epochs (Table 5.2., Figure 5.7. and 5.9.), and further illustrates that the shorter the epoch and the lower the cut-point threshold, the more reported vigorous intensity PA reported.

For MVPA expressed with the Sirard et al. (2005) and Puyau et al. (2002) cut-points, a 1s epoch reported in excess of 100% more time engaging in MVPA, compared to a 60 s epoch (Table 5.2., Figure 5.10. and 5.11.). Additionally when using the Sirard et al. (2005) cut-points, the 1 and 5 s epochs reported significantly more MVPA compared to a 15, 30, 45 and 60 s epoch (Table 5.3., Figure 5.10.). Reilly et al. (2008) found a similar trend with MVPA values of 30 min reported using a 15 s epoch, and approximately 18 min with a 60 s epoch. Nilsson et al. (2002) reported MVPA values ranging from 49 min when expressed in a 5 s epoch to only 10 min in a 60 s epoch. When taking into consideration light PA, which generally appears to decrease with longer epochs, it would appear that by using longer epochs, short bouts of MVPA are summed with activity of light intensity within the same epoch. This leads to a masking effect and means that very short bouts of vigorous intensity PA as described by Bailey et al. (1995) and Basquet et al. (2007) are missed when using longer epochs. This is particularly pertinent in highly active populations such as Kenyan school children., where we have demonstrated epoch to have a more significant effect on very high level, vigorous PA (Table 5.2., Figure 5.7., 5.8. and 5.9.) which would ordinarily be missed if activity was monitored using a larger epoch.

When considering the three cut-point for MVPA (Table 2.1.), the Sirard et al. (2005) and Puyau et al. (2002) cut-points reported significantly more time engaging in MVPA compared to the Pate et al. (2006) cut-points (Table 5.2., Figures 5.10., 5.11., 5.12.). For example, MVPA calculated with Sirard et al. (2005) cut-point, gave values ranging from 73-28 min (Table 5.2, Figure 5.10.), for the Puyau et al. (2002) cut-point 59-36 min (Figure 5.11.), while the lower CPM MVPA value as calculated but Pate et al. (2006) cut-point gave a significantly higher range of 108-102 min across all epochs (Table 5.2., Figure 5.12.). These varied values are in agreement with the current literature (Reilly et al., 2008; Penpraze et al., 2006; Roberts et al., 2007; Anderson et al., 2005). Reilly et al. (2008) treated data with three different cut-points for MVPA, and reported values ranging from 28 min using the Puyau et al. (2002) cut-point, to 266 min using a lower CPM cut-point value from the Trost/Freedon et al. study (1997) when applied to the same group of children. Lower cut-point values such as the Pate et al. (2006) and Trost/Freedson et al. (1997) values for MVPA, lead to children crossing the CPM threshold for moderate intensity PA more frequently and therefore appearing to be more active than when MVPA is assessed using higher CPM threshold value such as the Puyau et al. (2002) and Sirard et al. (2005) (See Table 2.1. for CPM values). This was also illustrated in a study by Anderson et al. (2005) in an American cohort of children, where the lower Trost/Freedson et al. (1997) cut-points gave consistently higher values for MVPA, compared to the Puyau et al (2002) cut-points (Andersen et al., 2005). The Trost/Freedson et al. (1997) cut-points used in other studies are created from extrapolation from adult treadmill data, which may explain the trend to over estimate physical activity compared with other objective methods, such as HR monitoring (McKee et al., 2005), pedometry (Cardon et al., 2004) and when accelerometry has been linked to energy expenditure using doubly labeled water (Reilly et al., 2008). All have reported MVPA to be low. However, the Pate et al. (2006) cut-points used in our study, were created from calibration studies which were cross-referenced with free living PA, thus opening up the study to investigator bias, leading to mis-classification of certain activities. Overall though, it would seem one should be wary of comparing data expressed using different cut-point values, as this and other studies have come to the conclusion that is can greatly effect how active or inactive a population can appear (Reilly et al., 2008; Penpraze et al., 2006; Roberts et al., 2007; Anderson et al., 2005).

Both epoch and cut-point had a significant effect on the percentage of children attaining the current guidelines for PA (Cavill et al., 1997; US Dept Health, 2001), when expressed using the Sirard et al (2005) and Puyau et al. (2002) cut-points (Table 5.2.). For the Sirard et al. (2005) cut-point, a 1 s epoch suggested 57% of children were taking part in at least 60 min of MVPA per day, whilst a 60 s epoch suggested only 10%. For the Puyau et al. (2002) cut-point, a 1 s epoch suggested 38% were attaining the guidelines, whilst in a 60 s epoch only 19%. For the Pate et al. (2006) cut-point, epoch had no effect although the percentages of children attaining the guidelines were much higher (95%, Table 5.2.). Again this is due to the lower CPM value. The use of a lower cut-point value may be more appropriate for this study population as the questionnaire data would suggest that the majority of children were walking or running to school for at least 30 min per day, and all were taking part in active house hold chores such as fetching water and herding cattle, as well as active games in any free time (Table 5.1.). Therefore, one would expect more than 57% of the children to be reaching the current guidelines for PA as reported using the Sirard et al. (2005) cut-point with data expressed in a 1 s epoch which has been shown here to be more sensitive to vigorous PA. However all of the cut-point values used in this study have been developed from western children of specific ages (Pate et al (2006) and Sirard et al (2005), age 3-5, Reilly et al., (2005) and Puyau et al., (2002) age 6-16, which were not matched to the study group under investigation here where ages ranged from 4 – 16 years (Table 5.1.). Additionally, no cut-point values have been created specifically for all the epochs under investigation, with a 15 s epoch being the shortest epoch that cut-points have been created for (Pate et al., 2006; Sirard et al., 2005.). Such 'mis-matches' may lead to further underestimation of MVPA however, it is impractical to create a new set of cut-points for every population and epoch, and some groups such as Welk (2005) and Stone et al. (2009) have strongly suggested that the creation of yet more cut-point values would lead to further confusion when attempting to compare data to the current literature.

This study has clearly demonstrated the effect both epoch and cut-point has on reported PA levels in a highly active population of Kenyan school children (Table 5.2., Figure 5.1.-5.12.). Shorter epochs may be more appropriate for assessing PA in highly active children, where short bouts of high PA may be missed by longer epochs. However, where sedentary activity is of interest, epoch and cut-point appears to have little impact on the number of minutes of this type of activity reported. Additionally, one must be wary of applying previously published cut-points to accelerometry data, as they can impact on how active or inactive a population appears (Table 5.2; Figures 5.1-5.12). Ideally, individual cut-point values should be created for each population and for each epoch used. However, this is not always practical and may in fact lead to further confusion preventing data being compared between study groups (Stone et al. 2009; Welk, 2005). When applying cut-points, the quality of calibration and the feasibility of the results compared to, say a PA questionnaire or observations, should always be considered. Additionally, even though it is clear from the results presented here, that cut-point, and in particular epoch, has a significant effect on reported PA levels, the actual physiological significance of attaining say, 59 min MVPA vs. 36 min MVPA per day (Puyau et al. 2002; Table 5.2; Figure 5.11.), has yet to be determined (Reilly et al., 2008). Do these small, brief bouts of vigorous PA measured when using smaller epochs actually contribute to the suggested health benefits of taking part in 60 min MVPA per day (Cavill et al., 1997, US Dept Health, 2001)? Currently the guidelines fail to specify the duration of moderate PA required to gain health benefits such as a reduced risk of cardiovascular disease, asthma, diabetes and overall body fat (Cavill et al. 2001). Therefore, more studies are required in order to ascertain what 'type' of MVPA is of benefit to children, before any conclusions can be drawn on the use of cut-points and shorter epochs in particular.

7. Conclusions

We can conclude from these results that in this small cross section of Kenyan school children, both epoch and cut-points do have a vast effect in reported PA, but seem to have less of an effect on reports of sedentary behaviour. Therefore, where sedentary behaviour is of interest, epoch and cut-point have little effect. However, where PA is of interest, it would appear from our results that both epoch and cut-point impact on how active or inactive a population appear. Smaller epochs lead to reports of more minutes of MVPA and longer epochs seem to mask PA of both a moderate and vigorous nature therefore leading to underestimations of PA. Additionally, lower cut-point values lead to higher reports of MVPA and the feasibility of achieving such levels must be taken into consideration. Additionally, it would appear that this small group of Kenyan school children are in fact highly active compared to their western counterparts, although a larger study on hundreds more individuals is required before any conclusions can be made on the population as a whole. Overall one must be wary when comparing PA as calculated using different cut-point and epoch and smaller epochs must be used when the aim is to measure how physically active a population are.

8. References

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9. Appendices

Appendix 1. Ethical Approval from IREC

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471//2/3

MOI UNIVERSITY
SCHOOL OF MEDICINE
P.O. BOX 4606
ELDORET
Tel: 33471/2/3

Reference: IREC/2007/95
Approval Number: 000339

25th September, 2008

Robert Ojiambo Mang'eni,
Moi University,
School of Medicine,
Medical Physiology Department,
P.O. Box 4606,
ELDORET.

Dear Mr. Mang'eni,

RE: FORMAL APPROVAL

The Institutional Research and Ethics Committee has reviewed your research proposal titled:

"Genetic Influences on body composition, exercise capacity, physical activity levels and energy expenditure in Kenyan Children from rural and urban areas".

Your proposal has been granted a Formal Approval Number: **FAN: IREC 000339** on 25th September, 2008. You are therefore permitted to commence your investigations.

Note that this approval is for 1 year; it will thus expire on 24th September, 2009. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date.

You are required to submit progress report(s) regularly as dictated by your proposal. Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. The Committee expects to receive a final report at the end of the study.

Yours Sincerely,

PROF. D. NGARE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
APPROVED
02 OCT 2008
P. O. Box 4606 ELDORET

cc:	Director	-	MTRH
	Dean	-	SOM
	Dean	-	SPH
	Dean	-	SOD

Appendix 2. Physical Activity Questionnaire

Determination of Physical Activity Levels of Kenyan Children using Accelerometry

Physical Activity Questionnaire

Name:

1. How old are you?

2. Where do you live? Urban ☐ ☐

3. What duties do you do at home involving physical activity:

   Household chores ☐ Gardening ☐

   Cattle herding ☐ None ☐

Others (please specify)…………………………………......

4. What time do you wake up in the morning?

   ………………

5. What time do you go to sleep?

   ………………

6. How do you get to school?

Car ☐ Bicycle ☐ Running ☐ Walking ☐

7. How far is your school from your home?

Not Very Far ☐ Near ☐ Far ☐

8. How long does it take for you to get to school?

<30 min ☐ >30 min < 1 hour☐ >1 hour ☐

9. Where are you playing activities at school?

……………………………………………

10. Where are your leisure activities at home?

………………………………………………

11. How do you spend most of your time in school?

Seated ☐ Walking/running ☐

12. How do you spend most of your time at home?

Seated ☐ Walking/running ☐

13. What is your favorite sport?

…………………………………………………