CODEN [USA]: IAJPBB ISSN: 2349-7750

INDO AMERICAN JOURNAL OF
PHARMACEUTICAL SCIENCES
http://doi.org/10.5281/zenodo.2560907

Available online at: http://www.iajps.com *Review Article*

IMPACT OF ACTIVITY MONITORS ON QUANTIFICATION OF PHYSICAL ACTIVITY - A SYSTEMATIC REVIEW & META-ANALYSIS

AMNA AAMIR KHAN[1], Prof. Dr. PIRZADA QASIM RAZA SIDDIQUI[1], Dr. BASIT ANSARI[2], ALI FARHAD[1]

[1]Ziauddin College of Rehabilitation Sciences, Ziauddin University., Ziauddin University[1]., [2]Department of Health, Physical Education & Sports Sciences, University of Karachi., [1]Ziauddin College of Rehabilitation Sciences
Ziauddin University.

Abstract:

The aim of analysis was to determine the impact of different activity monitors for quantifying Physical Activity (PA) among the sedentary population for accurate measurement of Energy Expenditure (EE), Metabolic Equivalent (MET), 6 Minute Walk Test (6MWT) and Temporospatial parameters (TSPs) of Gait. The systemic review was performed in MEDLINE, PEDro, AMED, CINAHL, Scopus, Cochrane Central Trials of Register, PsychINFO, Embase databases. Nine qualitative and seven quantitative studies investigating regarding accelerometers with sedentary lifestyle population were selected with TSPs, EE, MET, 6MWT as outcome measures. Quality was assessed using Cochrane Collaboration Tool for assessing the risk of bias. Accelerometers were categorized into four groups; ActiGraph, activPAL mixed accelerometers and new generation accelerometers. Out of 105 studies, only 16 studies (2542 participants) met the inclusion criteria. The result obtained from the quantitative analysis shows that activPAL had more validity than any of the other accelerometers for the quantification of Physical Activity in free-living environment for sedentary behavior with pooled effect of 0.96 under random effect model followed by new generation accelerometers 0.771, mixed accelerometers 0.71 and ActiGraph older generation 0.682.Evidence presented in the paper reveals that a paradigm shift has been seen from subjective measurement approach to objective measurement due to the availability of several types of accelerometers. ActivPAL has found to be effective in the quantification of PA during lifestyle behaviors.

Keywords: *physical activity; sedentary lifestyle; activPAL; ActiGraph; research-grade activity monitor.*

Corresponding author:

Amna Aamir Khan,

Ziauddin College of Rehabilitation Sciences, Ziauddin University.

QR code

Please cite this article in press Amna Aamir Khan et al., ***Impact Of Activity Monitors On Quantification Of Physical Activity - A Systematic Review & Meta-Analysis.,*** *Indo Am. J. P. Sci, 2019; 06(02).*

INTRODUCTION:

Quantification of Physical Activity (PA) is claimed to be an essential facet in nearly all types of epidemiological studies; correlating with the outcomes measures such as temporo-spatial parameter of Gait (gait velocity and cadence), Energy Expenditure (EE) and Metabolic Equivalent Term (MET) as a dependent variable with duration and frequency of the physical interventional strategies as an independent variables. It is well evident that physical activity is inversely related to different health care conditions that impact the lifestyles of the patients [1]. Approximately, 23% of world population are reported as insufficiently active and recommended by World Health Organization to decrease it further up to 10% by 2020 [2].Therefore the need of physical activity measurement approaches to quantify the amount and type of movement in adults with different settings is highlighted in different researches [3]. Accurate assessment of Physical Activity is essential in investigating the impact of dose response on specific health outcomes especially among sedentary life style individuals [4]. Initially self-reported questionnaires and observations that were a part of subjective measurement (SM) were used to estimate the sedentary time and PA but due to decreased reliability and validity the researchers started questioning it [5]. A number of challenges were associated with SM especially among adult population [6] still is popularly used due to its simplicity, durability and comfort ability in the clinical as well as laboratory settings. Although these self-reported activities are easy to use and can be conducted on a larger scale but are subjected to observer bias, [4] perception bias and recall bias [7]. Hence the need of moving from subjective quantification of Physical Activity towards objective approach arises.

Accelerometers have enabled the clinician in general and researchers, in particular, to move towards an objective measurement thereby allowing a paradigm shift in quantifying the physical activity more precisely and accurately [8] however that shift brings with itself some perplexities towards the use of different accelerometers. As numbers of competing accelerometers are available for use it is difficult to identify which type of accelerometer is optimally appropriate for measuring of Physical Activity and Sedentary behavior among population under study[9]. Today, the objective approach for measuring Physical Activity can be achieved through various accelerometers which are widely divided into two main groups 1) Research- Grade Activity Monitors and 2) Consumer-Grade Activity Monitors [10]. Besides them Doubly-Labeled water, Direct Calorimeter and Indirect Calorimeter (CosMed K4b2) are widely been used as an objective approach with certain limitations of portability and free environmental movement; these instruments are now confined in laboratories rather than on-field studies [11]. Consumer-Grade Activity Monitors are one of the most commonly used devices for measuring PA, EE and METS in free living-environment with cosmetic outlook and are easily interpretable thereby gaining popularity among different populations particularly among youths [12]. Yet its validity and reliability is highly questionable. In addition to it these devices have an estimated Mean Absolute Percent Error of around 27% to 36% for Energy Expenditure to measure EE by the CosMed K4b2 during an eight activity protocol therefore decreasing the credibility of these devices, due to its large mean error [8]. On the other hand, research grade activity monitors are widely used by the researchers on different versions and types of activity monitors worn. However, due to rapid advancement in technology on daily basis, the need of population-based studies has taken the attention of both clinicians as well as researchers for the quantification of Physical Activity [13]. Also, the unavailability of old and obsolete versions in the market has created a gap in the literature for these population-based studies using monitors to determine the sedentary, light, moderate as well as vigorous activities especially in young adults [14]. In one such trial, the criterion validity was determined by using two different Research Grade Monitors activPAL and ActiGraph that has shown a strong validity [15] in determining the difference in occupational sitting and standing time. Similarly, these results have been further acknowledged in another study where activPAL was found to be a valid tool to measure components of sedentary behavior in free-living environment among different occupational population [16]. Contrarily, in another study no significant difference was noticed in the results between ActiGraph and activPAL while performing light to moderate activities. Interestingly, it has been observed that sedentary activities performed by participants in both devices are similarly recorded yet these devices are not used interchangeably [17]. A study conducted on determining the criterion validity for EE in sedentary and light activities concluded that among different wearable monitors including activPAL, ActiGraph and Sense Wear 2; activPAL have better validity for estimating physical activity in Sedentary Behavior (SB) and Light-intensity Physical Activity (LPA) [18]. Further, it was recommended that activPAL could be a mode of choice for the researchers in estimating physical activity during SB and LPA [18]. Therefore the aim of systematic review and meta-analysis is to determine the impact of different activity monitors by quantifying Physical Activity (PA) for accurate measurement of Energy Expenditure, Metabolic Equivalent Term and Gait in order to provide a pooled effect of measuring activity monitors in a single study in sedentary or free-living environment.

MATERIALS AND METHODS:

Study Selection Criteria

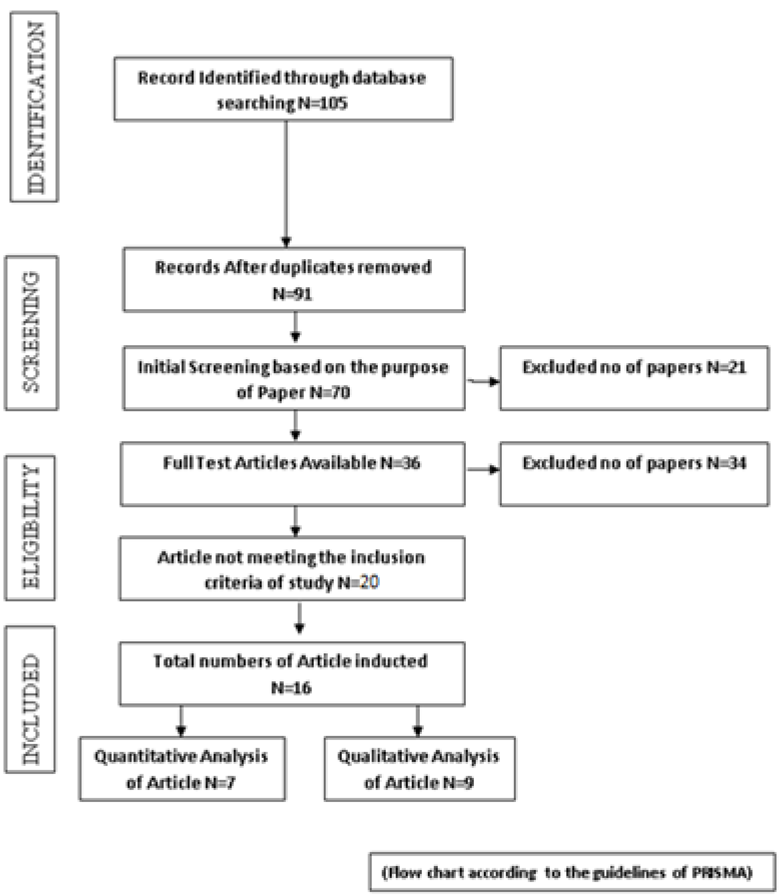
The studies that were using accelerometers of any type among the Physically inactive individuals with the sedentary lifestyle, using the outcomes measures such as temporo-spatial parameters of Gait (gait velocity and cadence), Energy Expenditure (EE) and Metabolic Equivalent Term (MET), 6 Minute Walk Test (6MWT).

Data Sources and Search Strategy

An electronic search was completed on 105 peer-reviewed published research studies related to accelerometers, activPAL, ActiGraph, footwear accelerometers, gait analysis, subjective and objective assessment of gait. As the paradigm shift mostly from subjective measurement approaches to objective measurement mostly occurred in the tenure between 2010 to 2018so eight databases including MEDLINE, PEDro, AMED, CINAHL, Scopus, Cochrane Central Trials of Register, PsychINFO and Embase were searched from 2010 to June 2018.

The search strategy was formulated by two reviewers and included terms such as; 'accelerometers', 'activPAL', ActiGraph', 'subjective measurement approach', 'objective measurement approach', 'physical fitness' using Boolean logic 'AND', 'OR' and 'NOT' in between them.

Titles and abstracts found through the electronic search were initially screened by two reviewers. Then these two reviewers independently assessed for full text articles in which articles were excluded due to the non-availability of the full text. Any disagreement, when occurred, between the two reviewers were then resolved through discussion followed by consensus. If the consensus was not achieved then the third reviewer was contacted (Figure 1).



The Schematic representation of searches carried out for the paper is shown in Figure 1

Inclusion/Exclusion Criteria
All those studies available as full-text article using activity monitors/accelerometers as of any kind, quantifying Physical Activities in sedentary lifestyle condition and correlating accelerometer recordings with direct observations were included in the quantitative analysis and the studies using accelerometers but not evaluating it with direct observations are included in the qualitative analysis of the paper. Studies using subjective approach for quantifying Physical Activities and are analyzing Gait cycle through accelerometers and studies conducted before 2010 are excluded from the paper.

Data Extraction& Quality Assessment

Quality of all the selected studies was assessed using the Tool for Assessing Risk of Bias considering Cochrane Collaboration [19]. Risk of bias was scored as low, high and unknown on the basis of participant selection bias, performance bias, detection bias, attrition bias and reporting bias (Table 1). The data extracted from the study includes correlation coefficient of accelerometers with direct outcome measures in term of Physical Activity, Metabolic Equivalent Terms (METs), 6MWTS and GAIT parameters (Cadence, Gait velocity, Stride length) during sedentary and light activities (lying, sitting standing).The description is shown in Table 2a, 2b.

Risk of bias was analyzed on the basis of Cochrane collaboration tools for assessing the risk of bias.

Table 1: Summary of Risk of Bias for each included study is illustrated

Study Included	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome assessment	Incomplete outcome data	Selective reporting
Sandroff et al. 2014 [21]	×	×	×	√	×	?
Koster at al. 2016 [27]	×	×	×	√	√	√
Celis-Morales et al. 2012 [7]	×	×	×	√	×	?
Herbolsheimer et al. 2018 [25]	√	√	√	√	√	√
John D et al.2010 [28]	√	√	√	√	√	√
van Nassau et al. 2015 [15]	√	√	√	√	√	?
Cleland et al. 2013 [29]	×	×	×	√	×	√
Song et al. 2010 [30]	√	√	√	√	?	√
Lyden et al. 2012 [16]	√	√	√	√	?	?
Cain et al. 2013 [31]	√	√	√	√	√	√
Dowd et al. 2012 [24]	√	×	√	√	×	?
Edbrooke et al. 2012 [22]	√	×	√	√	×	√
Kelly et al. 2013 [33]	√	√	√	√	?	√
Lee et al. 2011 [23]	√	×	√	√	?	√
Kozey-Keadle et al. 2011 [32]	√	√	√	√	×	√
Blythe et al. 2017 [8]	×	×	×	√	?	√
√= Low Risk of bias × = High risk of bias ? = Unknown risk of bias						

Data Synthesis and Analysis
Similar outcome measures were combined in a meta-analysis using Hedge g equation to determine fixed effect model, heterogeneity in the outcomes was identified using I^2. Effect sizes were estimated as Coefficient of correlation between the research grade activity monitors, consumer-grade activity monitors and the standard protocols used in the study. The studies were combined for the quantitative analysis of the data in which the value of the coefficient of correlation was given regardless of the missing data imputed by researchers. MedCalc statistical software was used for the quantitative analysis [20].

Table 2 a) Summarizes the details of study used for Qualitative analysis

Study	Sample size	Study duration	Study design	Qualitative Analysis	Primary Outcome	Secondary outcome
Koster et al. 2016 [27]	62	1 week	Longitudinal study	Analysis of result on the basis of the device working principal ActiGraph and activPAL	PA	-
Celis-Morales et al.2012 [7]	317	1 week	Longitudinal study	Accelerometer and IPAQ reading with different biomarkers	Subjective assessment of PA using IPAQ	Relationship between ActiGraph-derived sedentary time and IPAQ-reported sitting time and vascular and metabolic risk factors
Herbolsheimer et al. 2018 [25]	1172	N/A-	Cross-sectional	Self-reported and accelerometer-accessed PA	LAPAQ assessment	association between cognitive function and MPA
John et al.2010 [28]	8	N/A	Cross-sectional	Types of ActiGraph accelerometers during walking and running	PA (Sedentary, Light and Moderate)	-
Cleland et al. 2013 [29]	8	N/A	Cross-sectional	Methodological Analysis related to the placement of different models of accelerometers	Quantification of PA from sedentary to intense	-
Song et al.2010 [30]	519	1 week	Longitudinal study	An accelerometer in the free-living environment among elderly patients	PA on the daily routine	-
Cain et al.2013 [31]	25	75 days	Longitudinal study	Comparison of Older and new generation of ActiGraph	PA Sedentary lifestyle	-
Lee et al.2011 [23]	18	N/A	Cross-sectional	Detection of fall by an accelerometer at varying speed	Stimulated falls four different type (forward, backward, lateral (left and right)	-
Blythe et al. 2017 [8]	50	N/A	Longitudinal Study	Consumer-Based Accelerometers validity	PA during different lifestyle condition	-

Studies were divided into four categories according to their estimation of validity: a) ActiGraph b) activPAL c) mixed accelerometers d) updated ActiGraph models (LFE and 331triaxial). The pooled correlation of coefficient with 95% of C.I was calculated using a forest plot for each (figure 3).

Table 2 b) Summarizes the details of study used for Quantitative analysis

Study	Sample Size	Study Deign	Quantitative Analysis	Outcome
Sandroff et al. 2014 [21]	63	Cross-sectional	Between ActiGraph and Step watch	6 MWT
van Nassau et al. 2015 [15]	42	Cross-sectional	ActiGraph and activPAL comparison keeping activPAL as gold standard	Occupational Sedentary Activity
Lyden et al.2012 [16]	13	Cross-sectional	ActiGraph(Norm), ActiGraph(LFE) and activPAL	PA during Sedentary Behavior
Dowd et al.2012 [24]	13	Cross-sectional	ActiGraph and activPAL validity keeping indirect calorimeter CosMed k4b2 as a gold standard	PA monitoring
Edbrooke et al. 2012 [22]	50	Cross-sectional	AMP 331 Footwear accelerometers validity keeping Direct Observation through VMS as a gold standard	PA
Kelly et al.2013 [33]	42	Cross-sectional	ActiGraph Intramodel validity	TSPs Count per Minute and VO2
Kozey-Keadle et al. 2010 [32]	20	Cross-sectional	Validation of ActiGraph and activPAL keeping direct observation as a gold standard	PA during sedentary lifestyle

RESULTS:

Results of Literature Search

Figure 1 shows the schematic representation of the literature search according to the PRISMA guidelines. Inclusion criteria were meet by sixteen studies providing adequate data to be included in the qualitative analysis (n=9) and qualitative analysis (n=7).

Characteristics of Included studies

Out of 16 studies (2452 participants), 7 studies were selected for quantitative analysis whereas 9 for qualitative analysis. Majority of studies used mixed gender population (n=14), 1 study targeted only males and 1 of females. Most of the studies included participants aged between 18–60 years (n=10) while five studies included participants older than 60 years of age.

For both qualitative and quantitative analysis seven studies used activPAL as an assessment measure of PA whereas eight studies used ActiGraph. Studies also used step watch, [21] AMP 331 [22] mobile phone technology [23], CosMed Kb42 [24], IPAQ [7] and LAPAQ [25] respectively.

Risk of bias of included studies

Figure 2 shows the risk of bias in terms of percentages in the studies.

Selection Bias

Almost 68.7% of studies reveal correct randomization hence reducing the risk of selection bias however 31.2% studies show that insufficient details were reported placing them at high-risk bias category. Interestingly in 50% of studies lack reporting regarding the allocation of the group was found; indicating that strict implementation of a random sequence was missing.

Performance Bias

Although it is difficult to blind the participants and the personnel in any study due to the usage of different accelerometers and participants expectations interestingly only25 % of studies reveal a high risk of performance biasness.

Detection Bias

Hundred percent of studies were at low risk of biasness due to the blinding of outcome assessment (PA, EE and MET) hence showing no influence of measurement.

Attrition Bias

The problem of incomplete reporting of outcome data was found in 31% of studies making them at high risk of bias. Moreover for 38% of studies the risk of bias was unclear.

Reporting Bias

Almost69% of studies was at low risk of biasness as the protocols were available whereas in 31% of studies the risk of biasness was unclear.

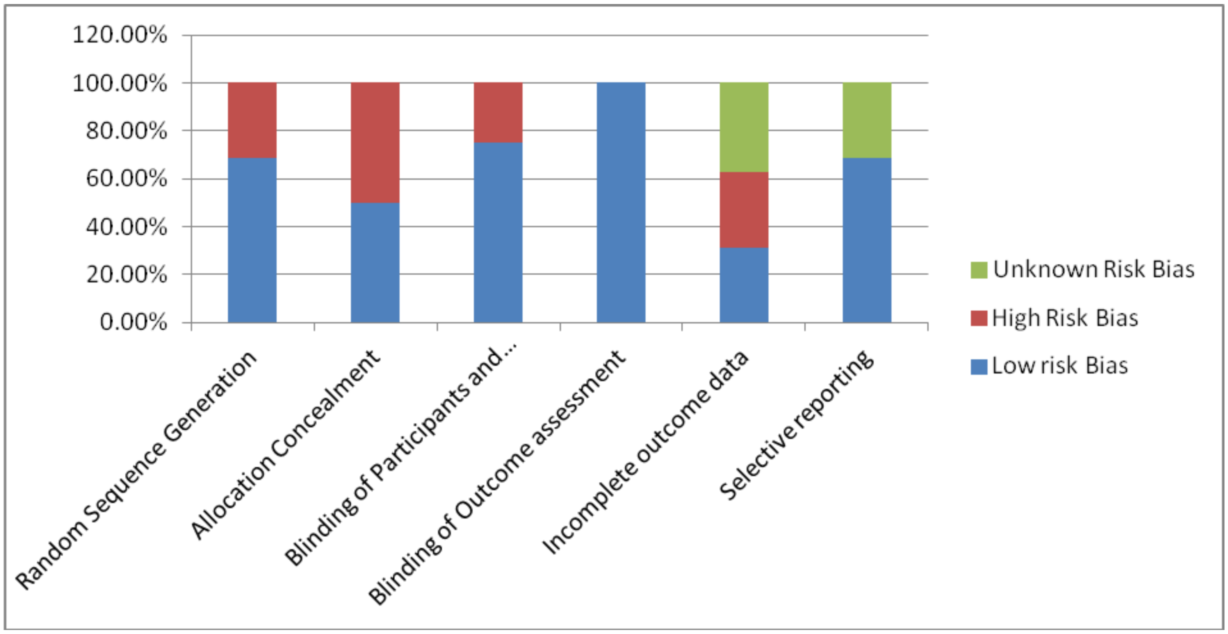


Figure 2: Risk of bias graph: review authors' judgment about each risk of bias item presented as percentages across all included studies.

Quantitative Analysis

Quantitative analysis of different studies included in this paper Hedges-Olkin method was used for calculating the weighted summary coefficient of correlation under a fixed effect model (Table 3). The studies were divided into four categories; studies estimated the validity of a) ActiGraph b) activPAL c) mixed accelerometers and updated ActiGraph models (LFE and 331triaxial). The pooled correlation of coefficient with 95% of C.I was calculated using a forest plot for each of the four categories as shown in figure 3.

Table 3: Shows the categories of accelerometers, correlation and level of significance

Study	Sample size	Correlation coefficient	95% CI	z	P	Weight (%)	
						Fixed	Random
Category A (ActiGraph)							
Sandroff et al 2014 [21]	63	0.37	0.13 to 0.56			34.29	18.68
van Nassau et al 2015 [15]	42	0.69	0.48 to 0.822			22.29	18.12
Lyden et al 2012 [16]	11	0.58	-0.03 to 0.87			4.57	13.60
Dowd et al 2012 [24]	15	0.96	0.88 to 0.98			6.86	15.19
Kelly et al 2013 [33]	42	0.88	0.78 to 0.93			22.29	18.12
Kozey-Keadle et al 2010 [32]	20	0.39	-0.06 to 0.71			9.71	16.31
Total (fixed effects)	193	0.68	0.59 to 0.75	11.02	<0.001	100.00	100.00
Total (random effects)	193	0.73	0.44 to 0.88	3.99	<0.001	100.00	100.00
Category B (activPAL)							
Lyden et al. 2012 [16]	13	0.99	0.96 to 0.99			25.64	30.36
Dowd et al 2013 [24]	15	0.96	0.88 to 0.98			30.77	32.71
Kozey-Keadle et al 2010 [32]	20	0.94	0.85 to 0.97			43.59	36.92
Total (fixed effects)	48	0.96	0.93 to 0.98	12.70	<0.001	100.00	100.00

Category C (mixed accelerometers)							
Standroff et al. 2014 [21]	63	0.37	0.13 to 0.56			77.92	50.41
Edbrooke et al. 2012 [22]	20	0.99	0.97 to 0.99			22.08	49.59
Total (fixed effects)	83	0.71	0.58 to 0.80	7.78	<0.001	100.00	100.00
Total (random effects)	83	0.90	-0.60 to 0.99	1.33	0.18	100.00	100.00
Category D(LFE and 331triaxial)							
Lyden et al. 2012 [16]	12	0.52	-0.07 to 0.84			18.75	35.91
Kelly et al. 2013 [33]	42	0.81	0.67 to 0.89			81.25	64.09
Total (fixed effects)	54	0.77	0.63 to 0.86	7.09	<0.001	100.00	100.00
Total (random effects)	54	0.73	0.39 to 0.89	3.51	<0.001	100.00	100.00

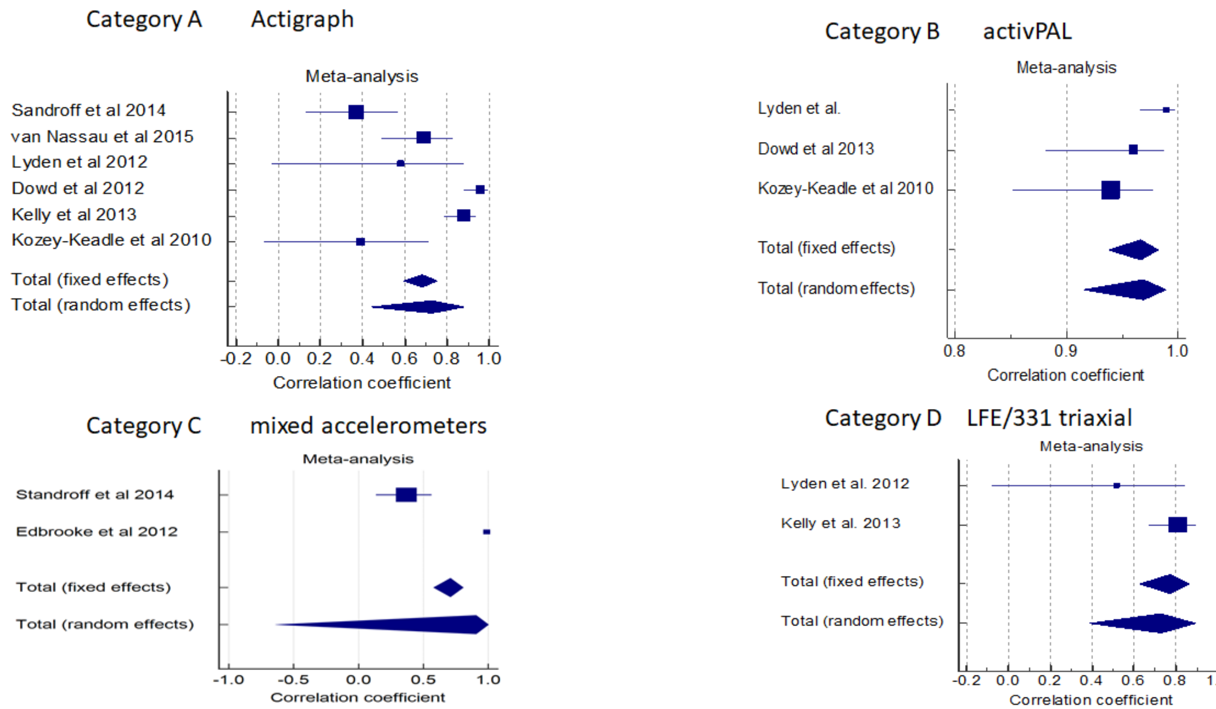


Figure 3: shows the Random Pooled Effect on the Forest Plot

The result obtained from the quantitative analysis of the study shows that activPAL had more validity than any of the other accelerometers for the quantification of the Physical Activity in free-living environment for sedentary behavior with the pooled effect of 0.96 under fixed effect model followed by new generation ActiGraph accelerometers 0.77, mixed accelerometers 0.71 and ActiGraph older generation 0.68.

Table 4: Represents the test for Heterogeneity

Category A (ActiGraph)	
Cochrane's Q Test	41.65
Degree of Freedom	5
Significance level	P < 0.00
I^2 (inconsistency)	88.00%
95% CI for I^2	76.35 to 93.91
Category B (activPAL)	
Cochrane's Q Test	5.33
Degree of Freedom	2
Significance level	P = 0.06
I^2 (inconsistency)	62.52%
95% CI for I^2	0.00 to 89.30
Category C (mixed accelerometers)	
Cochrane's Q Test	67.5531
Degree of Freedom	1
Significance level	P < 0.00
I^2 (inconsistency)	98.52%
95% CI for I^2	96.78 to 99.32
Category D(LFE and 331triaxial)	
Cochrane's Q Test	2.2176
Degree of Freedom	1
Significance level	P = 0.136
I^2 (inconsistency)	54.91%
95% CI for I^2	0.00 to 89.01

The test for heterogeneity shows that for all four categories the value of $I^2$was within the level of 95% of CI for I^2 which suggests that as for the higher value of heterogeneity the results were lined within the 95% of CI as mentioned in table 4.

Qualitative Analysis

For further confirmation of the result obtained from the quantitative analysis of the studies, qualitative analysis of 9 studies was performed. According to Mannini et al wrist wear accelerometers were less valid in comparison to foot wear [26]. Moreover, Koster et al found that hip and wrist wore ActiGraph accelerometers were providing similar data as that of activPAL during a free-living sedentary behavior [27].Conversely, Celis-Morales et al utilized International Physical Activity Questionnaire (IPAQ) and reported that subjective measurement approach is significantly strong reporting of PA for sedentary lifestyle condition when compared to different accelerometers like ActiGraph, ActiTrainer and others [7].On the other hand, John et al. reported that different models of ActiGraph had same reliability in measuring PA for sedentary and moderate-vigorous activity. However, it was concluded that still, it was preferable not to interchange models during the single episode of measurement of PA [28]. The interesting findings were provided in Cleland's study where the placement of the accelerometers at different position of the body was analyzed to find out the optimal placement. The performance of accelerometers for measuring the physical activity, six different locations was used in the study for the placement (chest, foot, hip, back, thigh and wrist) [29].Results reveal that hip-worn accelerometers acquired high average 0.97 in measuring eight different activities (lying, running, sitting, stairs down, stairs up, standing, walking, weighted) followed by thigh 0.97, chest 0.96, lower back 0.96, wrist 0.96 and foot 0.95. Furthermore, in measuring

the sedentary activities hip-worn accelerometers exclusively had a high F-measurement that is equals to 1 followed by thigh 0.97 [29].
Similarly, Song et al found that ActiGraph uniaxial accelerometers measured Physical Activity accurately and precisely among the osteoarthritic patients with activity limitations [30]. Cain et al found that newer generation ActiGraph was less accurate in measuring lower intense activities in comparison to the older generation. Also, these accelerometers either underestimate or overestimate the step count during quantification of sedentary PA behavior [31]. Lee et al found a unique approach by using accelerometers for the detection of fall; three trials of four different forms of falls were performed (backward, forward and left/right side bending). The recorded results show that different values of acceleration and deceleration during the ADLs provide a significant outcome to the threshold of fall [23].

In addition to it Blythe et al found that when a different model of consumer grade accelerometers were compared with CosMed K4b^2 device (indirect calorimeter) to measure EE; a Mean Absolute Percent Error (MAPE) of 30.1% to 61.8% was found, showing that consumer-grade accelerometers were not able to calculate physical activity precisely and accurately [8].

DISCUSSION:

A total of 16 studies were identified in which different types of accelerometers were used for the purpose of measuring physical activities; out of which 9 were qualitatively analyzed and 7 were analyzed quantitatively. The qualitative and quantitative analysis was performed on the basis of the statistical analysis being conducted in the study. All seven studies which were quantitatively analyzed were those which had calculated a reliability of accelerometers in comparison to some standard protocol whereas the qualitative analyses of all those studies were completed which had determined Physical Activity of the participants but did not compare its reliability with any standard protocol.
The results obtained from the analysis showed that among different types of research-based accelerometer activPAL had the greater reliability in measuring sedentary activity in comparison to other research-based accelerometers. The study conducted by Lyden et al in 2012 concluded that activPAL had more validity in measuring the physical activity in sedentary lifestyle condition in comparison to ActiGraph (AG-Norm and AG-LFE) which had overestimated the physical activity [16].

According to Lyden's research, to estimate the Physical Activity using ActiGarpah two different cut-points 100 counts/min and 150 counts/ min were set to determine sedentary time but both generations of ActiGraph did not accurately ensure Physical Activity as calculated by using ActivPAL [16]. Similarly, Kozey-Keadle et al also concluded that while measuring activities related to sedentary lifestyle behavior the researchers should prefer activPAL as it was more sensitive and reliable in quantifying the physical activities during a sedentary lifestyle [32]. Kelly et al identified the validity of two different generations of ActiGraph (Uni and Triaxial) and concluded that both generations of ActiGraph had the accuracy of 88.11% when compared to oxygen consumption (laboratory-based standard protocol). Kelly conducted a study on young adult participants and employed two generations of ActiGraph for measuring a physical activity [33].

An interesting study to determine the optimal placement of accelerometers in determining the Physical Activities was performed by Cleland et al. in 2013, according to Ian Cleland study, hip-worn accelerometers had highest performance index in measuring physical activity 0.97 followed by thigh-worn accelerometers 0.97. Therefore, the findings of this study concluded that hip was considered as the most practical site for wearing an accelerometer; as in human beings physical activities could pragmatically be measured from the site of hip (sitting, standing and walking) in comparison with any other site such as foot and wrist-worn accelerometers that only had the tendency to measure recordings during sitting and working on stations. Moreover, a number of participants habitually move their hands and foot while talking and sitting that results in recording false movements when no physical activity is being performed. Hence the hip worn accelerometers were found to have the highest precision index whereas foot worn had 0.95 [29].

With the advancement in the field, consumer-based accelerometers gained popularity among the researchers as well as industries because of its cosmetic out-looks. According to the study conducted by Blythe et al. the consumer-based accelerometers including Fitbit Charge 2, Samsung Gears and Apple Watch Series 2 had a Mean Absolute Percentage Error (MAPE) of around 37.4% to 61.8% when compared to indirect calorimeter (CosMed K4b^2) [8]. Though expensive (ranging from $100USD to $369USD) due to cosmetic outlook but the reliability was questionable.

Although a number of RCTs has been published revealing the importance of Physical activity monitors such as activPAL and ActiGraph yet no such filtered articles have been published in a review till date in which the pooled effects of preciseness of objective approaches of measurement has been determined. In authors belief the effort is first of its kind in which the objective and subjective approach has been highlighted. Moreover, with the advancement in technology new generation of research based activity monitors are available in the market and are widely used by the researchers yet are beyond the scope of this study that open the doors for studies conducted on larger scale with more number of articles.

CONCLUSION:

Our review article highlights on the essence of measurement of Physical Activity and Energy Expenditure through activPAL the thigh worn accelerometer that is found to be easy, reliable and valid tool for measuring in a free living environment. Hence, in conclusion though hip-worn accelerometers (ActiGraph) precisely measures all type of physical activity, activPAL could be a choice for researchers in future intending to measure physical activities during sedentary lifestyle behaviors.

List of Abbreviations

EE	Energy Expenditure
IPAQ	International Physical Activity Questionnaire
LAPAQ	LASA Physical Activity Questionnaire
LPA	Light-intensity Physical Activity
MAPE	Mean Absolute Percent Error
MET	Metabolic Equivalent
PA	Physical Activity
SM	subjective measurement
SB	Sedentary Behavior
TSPs	Temporospatial parameters
6MWT	6 Minute Walk Test

Acknowledgement

We would like to thank Ms. Sumaira Imran Farooqui for providing her guidance in publishing this meta-analysis.

Disclosure Statement

Authors declared no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES:

1. Gill JM, Bhopal R, Douglas A, Wallia S, Bhopal R, Sheikh A, Forbes JF, McKnight J, Sattar N, Murray G, Lean ME. Sitting time and waist circumference are associated with glycemia in UK South Asians: data from 1,228 adults screened for the PODOSA trial. *Diabetes Care*. 2011 Apr 1:DC_102313.
2. Benziger CP, Roth GA, Moran AE. The global burden of disease study and the preventable burden of NCD. *Glob Heart*. 2016 Dec 1;11(4):393-7.
3. Hills AP, Mokhtar N, Byrne NM. Assessment of physical activity and energy expenditure: an overview of objective measures. *Front Nutr*. 2014 Jun 16;1:5.
4. Gorman E, Hanson HM, Yang PH, Khan KM, Liu-Ambrose T, Ashe MC. Accelerometry analysis of physical activity and sedentary behavior in older adults: a systematic review and data analysis. *Eur Rev Aging Phys Act*. 2014 Apr;11(1):35.
5. Staudenmayer J, Pober D, Crouter S, Bassett D, Freedson P. An artificial neural network to estimate physical activity energy expenditure and identify physical activity type from an accelerometer. *J Appl Physiol*. 2009 Oct;107(4):1300-7.
6. Murphy SL. Review of physical activity measurement using accelerometers in older adults: considerations for research design and conduct. *Prev Med*.2009 Feb 1;48(2):108-14.
7. Celis-Morales CA, Perez-Bravo F, Ibanez L, Salas C, Bailey ME, Gill JM. Objective vs. self-reported physical activity and sedentary time: effects of measurement method on relationships with risk biomarkers. *PloS one*. 2012 May 9;7(5):e36345.
8. Blythe A, Scott E, LaMunion MS, Samuel R. Validity of Consumer-Based Physical Activity Monitors for Estimating Energy Expenditure in Youth. 2017.
9. Lee JM, Kim YW, Welk GJ. TRACK IT: Validity and utility of consumer-based physical activity monitors. *ACSMs Health Fit J*. 2014 Jul 1;18(4):16-21.
10. Hall KS, Howe CA, Rana SR, Martin CL, Morey MC. METs and accelerometry of walking in older

adults: standard versus measured energy cost. *Med Sci Sports Exerc*. 2013 Mar;45(3):574.
11. Crouter SE, Flynn JI, Bassett Jr DR. Estimating physical activity in youth using a wrist accelerometer. *Med Sci Sports Exerc*. 2015 May;47(5):944.
12. Ferguson T, Rowlands AV, Olds T, Maher C. The validity of consumer-level, activity monitors in healthy adults worn in free-living conditions: a cross-sectional study. *Int J Behav Nutr Phys Act*. 2015 Dec;12(1):42.
13. Dannecker KL, Sazonova NA, Melanson EL, Sazonov ES, Browning RC. A comparison of energy expenditure estimation of several physical activity monitors. *Med Sci Sports Exerc*. 2013 Nov;45(11):2105.
14. Whitaker KM, Pettee KG, Jacobs JD, Sidney S, Sternfeld B. Comparison of Two Generations of ActiGraph Accelerometers: The CARDIA Study. *Med Sci Sports Exerc*. 2018 Jun;50(6):1333-40.
15. van Nassau F, Chau JY, Lakerveld J, Bauman AE, van der Ploeg HP. Validity and responsiveness of four measures of occupational sitting and standing. *Int J Behav Nutr Phys Act*. 2015 Dec;12(1):144.
16. Lyden K, Kozey-Keadle SL, Staudenmayer JW, Freedson PS. Validity of two wearable monitors to estimate breaks from sedentary time. *Med Sci Sports Exerc*. 2012 Nov;44(11):2243.
17. Martin A, McNeill M, Penpraze V, Dall P, Granat M, Paton JY, Reilly JJ. Objective measurement of habitual sedentary behavior in pre-school children: comparison of activPAL With Actigraph monitors. *Pediatr Exerc Sci*. 2011 Nov;23(4):468-76.
18. Alberto FP, Nathanael M, Mathew B, Ainsworth BE. Wearable monitors criterion validity for energy expenditure in sedentary and light activities. *J Sport Health Sci*. 2017 Mar 1;6(1):103-10.
19. Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions 5.1. 0. The Cochrane Collaboration. 2011 Mar:33-49.
20. MedCalc for Windows. Version 16.2, vol. 1. Belgium: MedCalc Software, Ostend; 2016.
21. Sandroff BM, Motl RW, Pilutti LA, Learmonth YC, Ensari I, Dlugonski D, Klaren RE, Balantrapu S, Riskin BJ. Accuracy of StepWatch™ and ActiGraph accelerometers for measuring steps taken among persons with multiple sclerosis. *PloS one*. 2014 Apr 8;9(4):e93511.
22. Edbrooke L, Lythgo N, Goldsworthy U, Denehy L. Can an accelerometer-based monitor be used to accurately assess physical activity in a population of survivors of critical illness?. *Glob J Health Sci*. 2012 May;4(3):98.
23. Lee RY, Carlisle AJ. Detection of falls using accelerometers and mobile phone technology. *Age Ageing*. 2011 May 19;40(6):690-6.
24. Dowd KP, Harrington DM, Donnelly AE. Criterion and concurrent validity of the activPAL™ professional physical activity monitor in adolescent females. *PLoS One*. 2012 Oct 19;7(10):e47633.
25. Herbolsheimer F, Riepe MW, Peter R. Cognitive function and the agreement between self-reported and accelerometer-accessed physical activity. *BMC geriatrics*. 2018 Dec;18(1):56.
26. Mannini A, Intille SS, Rosenberger M, Sabatini AM, Haskell W. Activity recognition using a single accelerometer placed at the wrist or ankle. *Med Sci Sports Exerc* 2013 Nov;45(11):2193.
27. Koster A, Shiroma EJ, Caserotti P, Matthews CE, Chen KY, Glynn NW, Harris TB. Comparison of sedentary estimates between activPAL and hip-and wrist-worn ActiGraph. *Med Sci Sports Exerc*. 2016 Aug;48(8):1514.
28. John D, Tyo B, Bassett DR. Comparison of four ActiGraph accelerometers during walking and running. *Med Sci Sports Exerc*. 2010 Feb;42(2):368.
29. Cleland I, Kikhia B, Nugent C, Boytsov A, Hallberg J, Synnes K, McClean S, Finlay D. Optimal placement of accelerometers for the detection of everyday activities. *Sensors*. 2013 Jul 17;13(7):9183-200.
30. Song J, Semanik P, Sharma L, Chang RW, Hochberg MC, Mysiw WJ, Bathon JM, Eaton CB, Jackson R, Kwoh CK, Nevitt M. Assessing physical activity in persons with knee osteoarthritis using accelerometers: data from the osteoarthritis initiative. *Arthritis Care Res*. 2010 Dec;62(12):1724-32.
31. Cain KL, Conway TL, Adams MA, Husak LE, Sallis JF. Comparison of older and newer generations of ActiGraph accelerometers with the normal filter and the low frequency extension. . *Int J Behav Nutr Phys Act*. 2013 Dec;10(1):51.
32. Kozey-Keadle S, Libertine A, Lyden K, Staudenmayer J, Freedson PS. Validation of wearable monitors for assessing sedentary behavior. *Med Sci Sports Exerc*. 2011 Aug 1;43(8):1561-7.
33. Kelly LA, McMillan DG, Anderson A, Fippinger M, Fillerup G, Rider J. Validity of actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. *BMC medical physics*. 2013 Dec;13(1):5.