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Accelerometer-Measured Physical Activity and its Relationship with Body Mass Index (BMI) and Waist Circumference (WC) Measurements: A Cross-Sectional Study on Malaysian Adults

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ABSTRACT

Introduction: Physical activity has been shown to be beneficial for the prevention of obesity and non-communicable diseases. Our contemporary way of life that is technology dependent has significantly reduced physical activity. This study aimed to determine accelerometer-measured physical activity (moderate-to-vigorous physical activity (MVPA)) among adults in high and low walkability neighbourhoods in Penang and Kota Bharu, Malaysia. **Methods:** Participants (*n*=490) were sampled using multistage sampling method from neighbourhoods with varied levels of walkability using Geographical Information System (GIS). Physical activity was measured objectively using Actigraph GT3X+ accelerometers, worn by the participants on their waists for a period of 5 to 7 days. **Results:** The participants had a mean of 13.5 min/day of MVPA. Total MVPA was significantly higher among participants in high walkability neighbourhoods (19.7 min/day vs. 9.1 min/day). Results from *t*-test showed that the time spent on MVPA per day was significantly lower among participants residing in low walkability neighbourhoods. The final model of the MIXED model statistical tests showed that total MVPA was significantly associated with BMI, but not with WC measurements, after adjusting for covariates. **Conclusion:** Most of the participants had very low MVPA and did not achieve the current physical activity recommendations, implying that Malaysian adults residing in these two cities were not physically active to achieve health benefits. Results are suggestive of the importance of the walkability concept in neighbourhoods in encouraging physical activity and healthy body weight among Malaysians.

Key words: Accelerometry, moderate-to-vigorous physical activity, obesity, physical activity, walkability

INTRODUCTION

Overweight and obesity have become serious public health problems worldwide in recent decades, Major contributing factors include socio-economic, demo-graphics and built and natural environments (Amarasinghe & D'Souza, 2012; Bhurosy & Jeewon, 2014). Findings from the National Health and Morbidity Survey 2015 (NHMS, 2015) showed that the prevalence of overweight and obesity in Malaysia was 30.0% and 17.7%,

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respectively (Institute for Public Health (IPH), 2015). These figures show that almost half of the population in Malaysia are overweight or obese making Malaysia the fattest nation in South-east Asia.

Physical activity is defined as "any bodily movement produced by the skeletal muscles that requires energy expenditure" (Caspersen, Powell & Christenson, 1985). This includes a wide range of activities such as walking, exercising, swimming, dancing, working, playing, carrying out domestic and household chores, traveling from place to place (transportation) and engaging in recreational activities (WHO, 2015). Physical activity is the key determinant of energy balance, weight control and the prevention of obesity (Zoeller, 2007; WHO, 2010). It can reduce the risk of cardiovascular diseases, diabetes, strokes, and breast and colon cancer (WHO, 2010); Carlsson *et al*., 2016). Therefore, one of the public health priorities worldwide is to promote regular physical activity for the prevention of obesity (WHO, 2010). The WHO recommends that adults engage in at least 150 minutes of moderate-intensity physical activity, or at least 75 minutes of vigorous-intensity physical activity throughout the week. This can also be an equivalent combination of moderate- and vigorous-intensity activity; and all activities should be performed in bouts of at least 10 minutes or more for cardiorespiratory health (WHO, 2014).

The NHMS 2015 reported that the national prevalence of adults who were physically active was 66.5%, with males being significantly more active compared to females (IPH, 2015). Measured with the International Physical Activity Questionnaire (IPAQ) – Short Form, the majority of Malaysian adults were found to be "minimally active" (41.1% out of 66.5%) and only 25.4% of them were classified as "HEPA active". HEPA represents health enhancing physical activity, a high active category for individuals who exceed the minimum public health physical activity recommendations and an indication of greater health benefits. Meanwhile, in the Asia-Pacific region, a review article summarised that the prevalence of adults being "sufficiently active" was 83.0%, 93.0% and 85.0% in Australia, China and Hong Kong respectively, measured using the IPAQ – Short Form between the years 2002 to 2003. In Thailand, the prevalence of "sufficiently active" was 79.0% among Thai adults (in 2006 using IPAQ - Short Form) and 78.0% among Indonesian adults (in 2006 using Global Physical Activity Questionnaire, GPAQ) (Macniven, Bauman & Abouzeid, 2012).

Physical activity data at the population level for Malaysian adults relies heavily and is entirely based on self-reported measures at the moment. Questionnaire methods generally describe structured movements performed during exercise, sport, and work, and rely on participants' recall ability (Janz, 2006; Sylvia *et al*., 2014). Self-reporting of physical activity using questionnaires is cognitively difficult for adults and can be more challenging for the elderly and children (Janz, 2006). Self-report of physical activity is often found to overestimate physical activity levels (Troiano *et al*., 2008; Warner *et al*., 2012). Overestimation in self-reports is due to social desirability and/or the cognitive difficulty to remember the frequency and duration of different types of physical activity performed (Klasnja *et al*., 2008; Watkinson *et al*., 2010). Under-reporting and over-reporting of behaviours may also result in biased conclusions made pertaining to the correlates of physical activity behaviours (Cleland *et al*., 2011).

In contrast with self-reported physical activity, objective measurements of physical activity, or "recorded" data from activity monitors are free from recall bias and errors created by translation, misinterpretation and social desirability (Janz, 2006). This method could also

provide a more accurate estimate of physical activity duration, frequency, and intensity (Janz, 2006; Warren *et al*., 2010). The measurement of moderate intensity movement using other methods is difficult because this demands the assessment of many short duration activities performed in short bouts of time in different situations (Janz, 2006). Examples of these activities are household chores, child care, gardening and walking from place to place where relatively short episodes of moderate intensity physical activity are accumulated within daily routines. Total accelerometer-measured physical activity has been rarely reported for a representative sample of Malaysian adults.

Khoo & Morris (2012) in their review paper highlighted the importance of identifying key variables that influence physical activity behaviours. Socio-demographic factors that are associated with physical activity and physical inactivity should be identified to pinpoint population subgroups that should be targeted by interventions, programs, and policies for increasing physical activity in Malaysia.

The purpose of this study was to describe the total accelerometer-measured physical activity among a sample of Malaysian adults living in the neighbourhoods of Kota Bharu and Penang. This study also compared total physical activity, BMI, WC measurements and socio-demographic characteristics among adults living in low and high walkability neighbourhoods, and identified socio-demographic characteristics in relation to total physical activity among the participants of the study.

METHODS

Study design and sampling

This cross-sectional study was conducted in two cities in Malaysia, namely in the district of Kota Bharu, Kelantan and Penang Island, and was part of the IPEN-Malaysia study (IPEN: International Physical Activity and the Environment Network). The multistage sampling method was used for this study. All the administrative units (neighbourhoods) that matched specific physical characteristics (neighbourhood walkability) were stratified by high and low walkability. The participants (one from each selected household) were then selected from these neighbourhoods. Neighbourhood walkability was determined using the ArcGIS Version 10.2.2 software (Esri, Redlands, California, USA) according to its "walkability index", which is based on land use variables (mixed land use, intersection density, residential density) assessed using the Geographical Information System (GIS) (Kerr *et al*., 2013). Neighbourhood socio-economic status (SES) was determined using the aggregate and the geometric mean calculated statistically from the participants' reported income. Each neighbourhood was categorised as "high SES" or "low SES" based on the resulting aggregate and geometric mean values.

Adults aged between 20 to 65 years old who have lived in their neighbourhoods for at least 3 months prior to participating in the study, able to walk, and who agreed to participate in the study and equipped with written informed consent form were recruited as eligible participants in the study. The study was approved by Universiti Sains Malaysia Research Ethics Committee (Human) (FWA Reg. No: 00007718; IRB Reg. No: 00004494; Letter Reference Number: USMKK/PPP/JePeM [246.3(6)(1)].

Instruments

Objective-measurement of physical activity

The accelerometers Actigraph GT3X+ physical activity monitor (Actigraph, Pensacola, Florida, USA) were used to obtain an objective measurement of physical activity in this study. Accelerometer movement was recorded in

1-min time intervals. A valid accelerometer hour was defined as having no more than 60 consecutives 'zero' values or counts per minute (cpm). Participants were required to wear the accelerometer on their waists for seven consecutive days for at least twelve hours per day. The participants were asked to wear the accelerometer during all waking hours and to remove it during sleeping time and for any water-based activity.

The time spent (in minutes) on light, moderate, vigorous and very vigorous intensity physical activity recorded for every single accelerometer wearing day were generated using the ActiLife Version 6.13.2 software (Actigraph, Pensacola, FL, USA). Participants who had at least 5 or more valid days (inclusive of one weekend day) recorded in their respective accelerometers were accepted as successful and valid accelerometer wearing. The valid accelerometer data were scored with Freedson's cut-off point of 1952 counts per minute for moderate intensity to derive the outcome variable of mean minutes of MVPA per valid day (Freedson, Melanso & Sirard, 1998). These activity count cut-off points were then applied to the accelerometer data and total minutes at or above the moderate-to-vigorous physical activity (MVPA) threshold (inclusive of moderate, vigorous and very vigorous physical activity) obtained from each participant. The total MVPA measured refers to the total time spent on MVPA each day, regardless of whether the MVPA were performed continuously for 10 min or more (commonly known as MVPA bouts) or in shorter periods of less than 10 min.

Body Mass Index (BMI) and Waist Circumference (WC) measurements

Body weight was measured using a Seca digital weighing scale according to standard procedures (Model seca clara 803, Seca GMBH& Co. kg., Hamburg, Germany). A Seca body meter (Model Seca 203, Seca GMBH & Co. kg., Hamburg, Germany) was used to measure the height of the participants. The WHO BMI Classification was used to determine the BMI status of the participants. Waist circumference was measured using a measuring tape at the point of the minimal waist.

Socio-demographic characteristics

A self-administered questionnaire with items such as sex, age, marital status, education, ownership of motor vehicles, and other socio-demographic characteristics was answered by the participants.

Data analysis

The data were analysed using the IBM SPSS Statistics for Windows, Version 22.0 (Armonk, NY, USA). The level of significance was set at $p<0.05$. The outcome variable was total minutes of MVPA. The independent variables included sex, age, SES, education, motor vehicle ownership, marital status, and BMI and WC measurements.

RESULTS

Table 1 displays the descriptive statistics of the socio-demographic characteristics of the participants (n=490). The mean age of the participants is 40.0 (14.3) years and the mean number of motor vehicles ownership in each household is 2.7 (1.4). Among the participants, 64.7% are women; 61.8% are married or living with a partner; 50.8% are employed or have unpaid work outside the home; 33.9% have tertiary education (diploma and above); 71.4% are Malays and 73.7% have a driver's license. About 40% of the participants lived in the high walkability neighbourhoods in both Kota Bharu and Penang, and 43.5% of them are categorised as having high socio-economic status. Table 1 also shows the weight and height measurements, as well as the BMI status of the participants. The mean BMI and waist circumference measurement

Table 1. Socio-demographic characteristics and BMI status

Variable	*n*	*%*	*Mean (SD)*	*Median*
Age			40.0 (14.3)	42.0
Number of motor vehicles			2.7 (1.4)	2.0
Duration living in the neighbourhood (years)			14.1 (12.0)	12.0
Weight (kg)			65.4 (15.7)	65.0
Height (cm)			159.1 (8.9)	158.0
BMI (kg/m^2)			25.9 (6.0)	25.3
Waist circumference measurement (cm)			82.6 (14.2)	82.5
Sex				
Male	173	35.3		
Female	317	64.7		
Marital Status				
Not married nor living with partner	187	38.2		
Married/living with partner	303	61.8		
Employment Status				
No job or unpaid job outside the home	241	49.2		
Has a job or unpaid work outside the home	249	50.8		
Education Level				
Did not complete upper secondary school education (or equivalent)	123	25.1		
Completed upper secondary school education (or equivalent)	201	41.0		
Tertiary education or equivalent (Diploma and above)	166	33.9		
Ethnicity				
Malay	350	71.4		
Chinese	126	25.7		
Indian	11	2.2		
Others	3	0.6		
Monthly Income[a]				
Below RM 999.99	139	28.3		
RM 1,000.00 – RM 1,999.99	109	22.3		
RM 2,000.00 – RM 2,999.99	97	19.8		
RM 3,000.00 – RM 3,999.99	69	14.1		
RM 4,000.00 – RM 4,999.99	28	5.7		
RM 5,000.00 and above	48	9.8		
Driver's License				
Yes	361	73.7		
No	129	26.3		

Table 1. continued next page

Table 1. Continued

Variable	*n*	*%*	*Mean (SD)*	*Median*
Neighbourhood Walkability (Measured by GIS)[b]				
Low Walkability Neighbourhoods	294	60.0		
High Walkability Neighbourhoods	196	40.0		
Neighbourhood SES[c]				
Low SES Neighbourhoods	277	56.5		
High SES Neighbourhoods	213	43.5		
BMI Status (BMI in kg/m^2)				
Underweight (BMI < 18.5)	40	8.2		
Normal (BMI 18.5 – 24.9)	191	39.0		
Overweight (BMI 25.0 – 29.9)	151	30.8		
Obese (BMI >30.0)	105	22.0		

[a] Monthly income categories based on Economic Planning Unit's (EPU) distribution of households by income class in Malaysia.

[b] Neighbourhood walkability (low or high) was determined according to the "walkability index" based on land use variables (mixed land use, intersection density, residential density) assessed using GIS.

[c] Neighbourhood socio-economic status (low or high) based on the aggregate and geometric mean values calculated statistically from the participants' reported income.

are 25.9 (6.0) kg/m^2 and 82.6 (14.2) cm, respectively. Meanwhile, in Table 2, the accelerometer measurements show that the average accelerometer wear time is about 14.0 (1.6) hours per day. The mean minutes of total MVPA per day recorded by the accelerometers is 13.5 (14.0) min/day; while only 22.7% and 11.2% of the participants achieved 20 min and 30 min of MVPA per day, respectively. Total MVPA is the sum of moderate and vigorous intensity physical activity per day. A correlations test between total MVPA with BMI and waist circumference measurements indicates that both the BMI (r= -.219) and waist circumference measurements (r= -.134) are negatively correlated with total MVPA per day (p<0.01).

Table 3 shows the results of the t-test for total MVPA per day according to several socio-demographic characteristics and BMI status of the participants. Males are significantly more active, recording the mean total MVPA of 17.4 min/day compared to females who recorded a mean total MVPA of only 11.3 min/day. Malaysians who are married or living with a partner have a significantly lower mean total MVPA (10.6 min/day) compared to Malaysians who are not married (18.0 min/day). In terms of employment status, there is no significant difference in mean total MVPA between participants who have a job or have unpaid work outside home and unemployed participants. Having a driver's license has no impact on total MVPA among the participants.

Without controlling for any covariates, the mean of total MVPA recorded by the accelerometers is significantly higher among participants living in the high-walkability neighbourhoods. In terms of neighbourhood socio-economic status, there is no significant difference in the mean of total MVPA between low and high SES neighbourhoods. Subsequently, the participants were grouped into two groups, namely those with BMI less than 25 kg/m^2 and those with BMI equal to or more than 25 kg/m^2, respectively. The mean value of total MVPA is significantly lower among participants with BMI ≥ 25 kg/m^2.

Table 2. Accelerometer-measured physical activity measurements

Variable	*n*	*%*	*Mean (SD)*	*Median*
Accelerometer Measurements				
Accelerometer wear time (hour/day)			14.0 (1.6)	13.6
Sedentary time per day (min/day)			558.5 (111.2)	555.7
Light intensity physical activity per day (min/day)			262.6 (82.4)	255.7
Moderate intensity physical activity per day (min/day)			13.6 (19.2)	8.0
Vigorous intensity physical activity per day (min/day)			0.5 (2.4)	0.0
Total MVPA per day (min/day)			13.5 (14.0)	0.0
Achieved 30 minutes MVPA per day				
Yes	55	11.2		
No	432	88.2		
Missing accelerometer data	3	0.6		
Achieved 20 minutes MVPA per day				
Yes	111	22.7		
No	376	76.7		
Missing accelerometer data	3	0.6		

The MIXED model statistical test was applied to determine the association between total MVPA with BMI and waist circumference measurement. Only significant values at $p<0.05$ were included in the final model, which indicates the relationship between the total MVPA and BMI, as well as total MVPA and waist circumference measurements, after adjustments for covariates. Table 4 displays the final model that yields a negative association between total MVPA and BMI. Total MVPA (Estimate b= -.045) was inversely associated with BMI ($p<0.05$). Meanwhile, there is no significant association between total MVPA with waist circumference measurements; therefore, a final model is not reported.

DISCUSSION

The proportion of overweight and obese participants was 30.8% and 22.0%, respectively, while another 8.2% of them were underweight. These proportions were slightly higher than the reported figures in the NHMS 2015, where the prevalence of overweight and obesity among Malaysian adults was 30.0% and 17.7%, respectively (IPH, 2015). Results from the Global Burden of Disease Study by Ng *et al.* (2014) reported that 48.3% and 48.6% of Malaysian men and women had BMI of 25.0 kg/m^2 or greater. Similarly, results from a large-scale health survey conducted among adults in five different regions in Malaysia indicated that the prevalence of overweight was 33.6%, while the prevalence of obesity was 19.5% (Mohamud *et al.,* 2011). Findings from the present study and previous studies indicate that obesity remains and will continue to be a worrying public health challenge in the Malaysian adult population.

The mean total MVPA recorded by accelerometers worn by the participants in this study was 13.5 min/day. Male participants had higher MVPA as compared to female participants, as the mean values of total MVPA among men and women were 17.4 min/day and 11.3 min/day, respectively. The low total MVPA minutes recorded were similar to the MVPA

Table 3. Differences in total MVPA per day according to sociodemographic characteristics and BMI

Outcome	Total MVPA per day (min/day)			
	Mean (SD)	*95% CI for Mean difference*	*t*	*df*
Sex				
Male (*n*=171)	17.4 (1.1)	3.56, 8.71	4.68*	485
Female (*n*=316)	11.3 (13.3)			
Marital Status				
Not married nor living with partner (*n*=186)	18.0 (15.5)	4.87, 9.87	5.80**	485
Married/Living with partner (*n*=301)	10.6 (12.2)			
Employment status				
No job or unpaid job outside the home (*n*=240)	13.3 (13.4)	.78, -.35	-.28	485
Has a job or unpaid work outside the home (*n*=247)	13.6 (14.6)			
Driver's License				
Own a driver's license (*n*=360)	14.8 (14.9)	2.59, 8.23	3.77**	485
No driver's license (*n*=127)	9.4 (10.2)			
Neighbourhood walkability				
Low walkability neighbourhoods(*n*=291)	9.1 (9.6)	-12.98, -8.22	-8.75**	485
High walkability neighbourhoods (*n*=196)	19.7 (17.0)			
Neighbourhood SES				
Low SES neighbourhoods(*n*=275)	13.9 (15.6)	-1.38, 3.67	-8.87	485
High SES neighbourhoods(*n*=212)	12.8 (11.9)			
BMI Status				
BMI <25 kg/m^2 (*n*=229)	17.5 (16.9)	7.68, 1.23	6.24**	485
BMI ≥25 kg/m^2 (*n*=258)	9.8 (9.6)			

* $p < .05$, ** $p < .01$

recorded by a sample of working adults in the country with the KENZ Lifecorder PLUS uni-axial accelerometer; with MVPA values of 14.0 min/day and 11.4 min/day among males and females, respectively (Mohd Rizal *et al.*, 2016). Larger studies that utilised self-reported measures of physical activity such as the nationwide Malaysian Adult Nutrition Survey (MANS) and the 3rd NHMS all indicated that males were more active than women (Poh *et al*., 2010; Cheah & Poh, 2014). However, a study by Aslesh and colleagues (2006) on physical activity of adults in Kerala, India did not find any difference in total physical activity between men and women. The authors found that marital status (unmarried status) and occupation category (unskilled job vs unemployed/retired) were significantly associated with higher physical activity levels (Aslesh *et al*., 2016). The present study indicated that adults who were neither married nor living with a partner spent more time on MVPA, and there was no significant difference in mean total MVPA in relation to employment status.

In this present study, only 11.2% of the participants achieved 30 min of MVPA per day, as per recommendations of 30 min of moderate physical activity on most days of the week by WHO (2014). When categorised according to the 20 min of MVPA per day cut-off point, the proportion of participants achieving the cut-off point

Table 4. Associations of accelerometer-measured physical activity (Total MVPA) with BMI

Variables	*Estimate b*	*t*	*95% CI*	*p*
Total MVPA	-.045	-2.161	-.087, .004	< .050
	Estimate b	*t*	*95% CI*	*p*
Age	.062		.017, 108	< .010
Sex	-.921		-2.009, .168	.097
Marital status	-1.474		-2.704, -.243	< .050
Education	.522		-1.001, 2.045	.501
Employment status	-.826		-1.846, .193	.112
City (site)	.769		-.896, 2.435	.338
Neighbourhood SES	-.439		-1.670, .792	.459
Neighbourhood walkability	.364		-1.247, 1.975	.638
Number of motor vehicles	-.240		-.582, .101	.167
Average valid accelerometer wearing hours per day	.024		-.286, .334	.879

Dependent variable: BMI

Note. Age, sex, marital status (married/living with partner or. single/without partner), education (less than upper secondary school, completed upper secondary school, or university degree), employment status (have a job, yes or no), city (site), socioeconomic status of neighbourhood (high or low), objective walkability (high or low), number of motor vehicles owned, and average of valid accelerometer wearing hours per day were included as covariates in all models.

was only 22.7%. Thus, it can be implied that only a small proportion of participants in this study achieved the physical activity recommendations established by the WHO.

Meanwhile, neighbourhood walkability refers to an environment that supports walking and bicycling as modes of transportation and encourages physical activity. Walkable neighbourhoods have high residential density, mixed land use that places destinations near homes, and connected streets that provide direct routes from one destination to another (Sallis, 2011). Sallis and colleagues (2009) reported that individuals living in a neighbourhood with the most supportive environments were twice more likely to meet the recommended physical activity guidelines compared to those without any supportive environments. In the present study, participants living in low walkability neighbourhoods (9.1 min/day) had significantly lower mean MVPA compared to those who lived in high walkability neighbourhoods (19.7 min/day).

Meanwhile, Soon and colleagues (2011) reported that total daily energy expenditure recorded (a result of physical activity) was positively correlated with BMI and waist circumference in their study. Increased steps achieved per day were associated with a decrease in BMI, and physical activity was also proven to be inversely associated with the prevalence of metabolic syndrome (Soon *et al*., 2011). This is similar to the current study, where the total MVPA per day was negatively correlated with both the BMI and waist circumference measurement (p<0.01).

After adjusting for covariates, the total MVPA per day was inversely associated with BMI, but not waist circumference measurement. While

the present study found associations between physical activity with BMI, but not with waist circumference, Hazizi *et al* (2012) found significant associations between accelerometer-measured physical activity levels with both BMI and waist circumference among a sample of working adults in Penang.

One of the main strengths of this study is the use of accelerometers for objective measurement of physical activity in a large sample of adults. Moreover, this study was also able to establish the association of physical activity with BMI after controlling for socio-demographic and neighbourhood environment covariates that might affect the outcome of the study. Nevertheless, objective measurement of physical activity using accelerometers in research is a fairly new method of physical activity monitoring in Malaysia. Different established cut-off points to determine MVPA and physical activity levels could be seen because of the differences in the accelerometer models and specifications, as well as the methodology of the study itself. Understanding the differences in the measurements is very important to enable comparisons between studies.

CONCLUSION AND RECOMMENDATIONS

Objective measurement of physical activity of the participants revealed that the participants in this study achieved an average of only 13.5 min/day of MVPA. Only a small percentage of participants achieved the physical activity recommendations made by WHO, indicating that the adults in this sample were highly inactive. These adults were not physically active to experience the benefits of physical activity, as highlighted by the alarmingly low total MVPA per day achieved by the participants. Results from this study also highlight and reinforce the fact that physical activity, particularly MVPA, is vital to maintain a healthy BMI for the people.

In the present study, the significant differences in physical activity between participants living in the high and low walkable neighbourhoods indicated the relevance of environment factors in affecting total physical activity. These findings provide strong justifications that public health agencies need to work together with other sectors such as urban planning, parks and recreations, and transportation in order to create healthier and more walkable neighbourhoods. The suggestion of making cities more activity-friendly could be an important step towards substantial long-term and sustainable solutions to reducing risk factors and diseases associated with physical inactivity.

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Conflict of interest

The authors declare that there is no conflict of interest.

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