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Pedometer Step Counts and Metabolic Syndrome Risk Factors in Middle School Students in Rural Michigan

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Abstract **BACKGROUND:** Childhood metabolic syndrome increases health risks in later life. Physical activity may moderate risk factors and incidence. Pedometers are a valid means of tracking physical activity in children. This study was developed to examine the impact of physical activity, as measured by pedometer counts, on risk factors in middle school children in a rural Midwestern community. **METHODS:** The Cardiovascular Health Intervention Program (CHIP) measures cardiovascular disease risk factors in rural Midwestern middle school students, and includes blood pressure, waist circumference, fasting blood glucose, high density lipoprotein, and triglyceride levels, allowing determination of metabolic syndrome incidence. In one community activity of fifth and sixth grade students pedometer monitoring was added for two separate weeks (December and April). Analysis was done with one way ANOVA and T-Tests. **RESULTS:** Fifty-four students participated in CHIP, 36 in the pedometer project. Winter and Spring step counts were different (p=0.00). Boys had a trend for higher step counts than girls, but sample size prevented this reaching significance (p=0.16). Two (3.7%) students met criteria for metabolic syndrome. Lower step counts were associated with HDL levels meeting risk factor criteria (p=0.028). **CONCLUSIONS:** Rates of metabolic syndrome and component risk were similar to those seen nationally. Seasonal weather variation may explain differences between December and April step counts. Additional studies of rural students are suggested, allowing pooling of populations to attain greater sample sizes.

Keywords: *adolescents, physical activity assessment, metabolic syndrome, risk factors, pedometers*

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1. Background

The International Diabetes Federation (IDF) criteria for a metabolic syndrome (MetS) diagnosis in children between 10 and 16 requires abdominal obesity and at least two additional clinical measures. Potential factors are elevated triglycerides, low high-density lipoprotein (HDL, elevated blood pressure, and increased plasma glucose. [1] Physical activity is a valuable tool for maintaining a healthy metabolic profile, and has been shown to increase HDL levels, assist with controlling blood pressure, lower fasting blood glucose levels, reduce obesity, and decrease the risk of developing hypertension, diabetes, and high cholesterol. [2,3,4,5] The prevalence of MetS in adolescents is lower in those with higher levels of physical activity. [6] Physical activity influences MetS risk factors by its effects on HDL, obesity, triglycerides, blood pressure, and plasma glucose. [7]

Metabolic syndrome in childhood is associated with adult hyperinsulinemia, hypertension, hyperlipidemia, type 2 diabetes, and cardiovascular disease along with an increased risk for all-cause mortality. [8,9] Metabolic syndrome tracks from childhood to adulthood, increasing risk for conditions such as type 2 diabetes, cardiovascular disease, and subclinical atherosclerosis in adulthood. [10,11,12,13] It has been suggested that the increased levels of highly sensitive C-reactive proteins and low grade inflammation associated with obesity are the pathology behind metabolic syndrome. [14,15,16]

Central obesity is a necessary component for the IDF definition of metabolic syndrome. A non-obese child does not meet the criteria for metabolic syndrome, even if other risk factors are present. [14] Rates of metabolic syndrome in children increase with excess weight, with prevalence of 3.3% in all children, 11.9% in overweight children, and 29.2% in obese children. [17] Obesity results from an energy imbalance through the excess intake of food and drink compared to expenditure through physical activity. [18] In addition to inactivity, living in a rural setting is also associated with obesity, making rural populations particularly vulnerable to obesity and metabolic syndrome. [19,20,21]

Several studies have reported that cold weather has a negative impact on physical activity, [22-28] however there is a lack of research regarding it impact on children in areas with substantial seasonal climate fluctuation, such as occur in the Midwest of the United States. Additionally, much of the research examining the effect of weather on physical activity in children does not control for the structured school day and free play differences often seen in winter and summer seasons. Physical activity differences have been found for children between the weekdays and weekends, [29,30,31,32] and between genders, with males being more physically active than females. [33,34,35,36]

Pedometers are a valid assessment of physical activity in children, [37,38,39,40] with advantages such as their low cost, ease of use, and objectivity. [41,42] However pedometers do not give information regarding time spent at different exercise intensities. [42] Using an international sample, Tudor-Locke and colleagues reported steps per day cut points of 12,000 for girls and 15,000 for boys being associated with a healthy body composition as measured by BMI. [43]

The purpose of this study was to determine whether a seasonal relationship exists between pedometer step count and the risk factors for Metabolic Syndrome among Midwestern fifth and sixth graders. Two studies were performed in a rural area of Michigan. Study 1 examined the correlations of MetS and pedometer step counts and was nested in the larger Cardiovascular Health Intervention Program (CHIP). It was hypothesized that lower physical activity, as measured by pedometer step count, would be associated with a higher number of risk factors for MetS. Study 2 compared pedometer step counts during winter and spring, between boys and girls, and examined daily fluctuation. It was hypothesized that boys would have higher step counts than girls, that step counts during the school year would be higher during a warm weather month than a cold weather month, and that step counts would be higher during weekends than weekdays for children in school. Understanding these relationships may help identify children at risk for Metabolic Syndrome earlier and may guide intervention to prevent further disease progression.

2. Methods

Two studies were conducted as part of this overall project. Study 1 was nested within the Cardiovascular Health Intervention Program. [43,44] CHIP is a university based program aimed at screening for cardiovascular disease risk and providing education to children about heart healthy lifestyle. The CHIP protocol included blood samples to measure fasting blood glucose and lipid levels. [43] Blood pressure and waist circumference were also measured. [43] Study 2 compared pedometer data from Study 1, which was collected in the winter, to pedometer data collected in the spring.

2.1. Participants

Participants for this study were drawn from a population of middle school students, age 10-12, living in a rural community in Central Michigan. Study 1 used data gathered from subjects enrolled in 5^{th} and 6^{th} grade classes (public and parochial) from one rural community (Figure 1). CHIP and the initial pedometer use in study 1 occurred in December. Study 2 included participants from the same classes. They were again offered the opportunity to wear a pedometer for a week in April so that cold and warm month counts could be compared (Figure 2). In order for a participant to be included in Study 1, they had to participate in CHIP and the December pedometer data collection period. Inclusion in Study 2 required participants to participate in both December and April step counts. Each study included parental consent forms and student assent forms. Projects were approved by the Institutional Review Board (IRB) of Central Michigan University. Figure 1 and Figure 2 show participant flow through the studies and documents any loss of participants due to incomplete data collection. The final samples were 54 participants in Study 1 and 36 in Study 2.

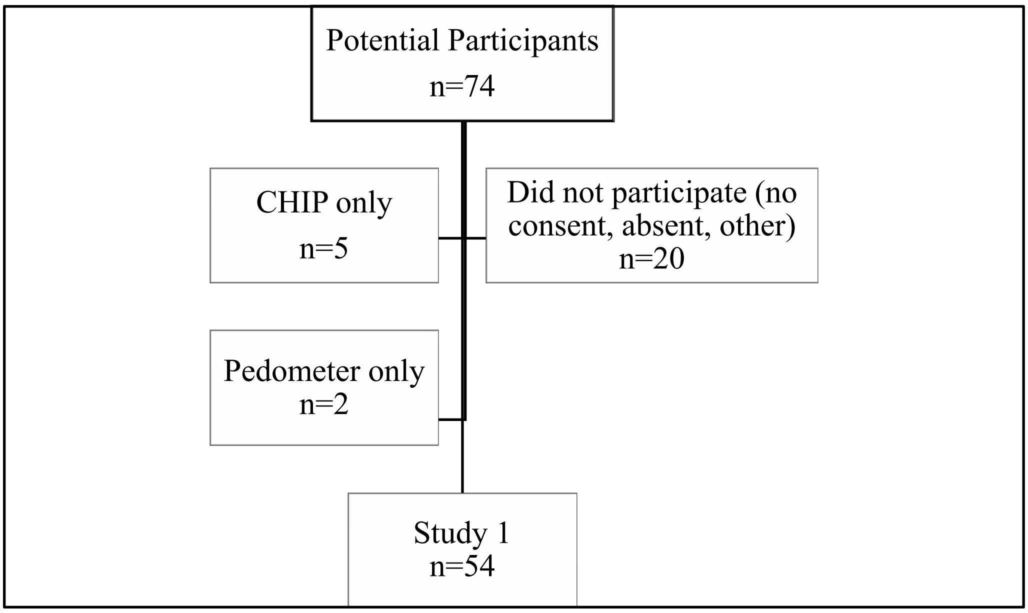

Figure 1. Recruitment and participant flow through Study 1

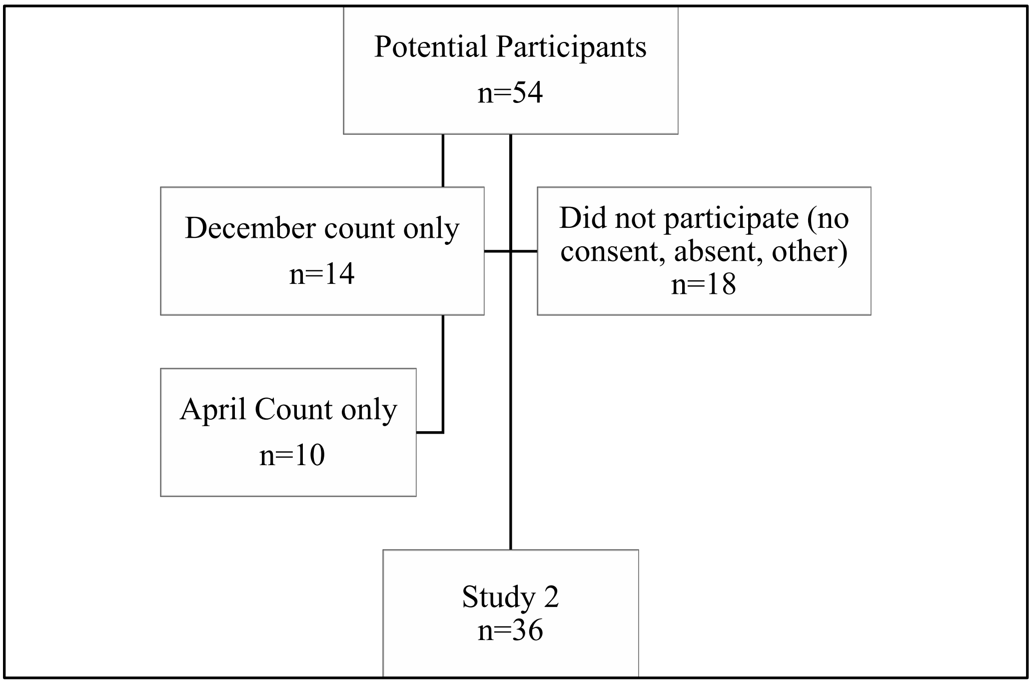

Figure 2. Recruitment and participant flow through Study 2

2.2. Procedure

Study 1 involved obtaining data from the CHIP regarding MetS risk factors including levels of plasma triglycerides, fasting glucose, and HDL-cholesterol as well as waist circumference and blood pressure. More details of the CHIP protocol are published in Peterson et al. [43] Pedometers (Accusplit model AE120XL, Accusplit, Inc, Livermore, CA) were issued to students to be worn for one calendar week. Both activities took place in December.

For Study 2, pedometers were reissued for a second week of data collection in April. Study 2 examined only those students who participated in both the December and April step counts. Pedometers were hand checked for functionality and accuracy before distribution to the students. Students were instructed in the daily use of the pedometers and given a step count recording sheet with additional space for an activity log where they could list activities such as sport or gym class.

2.3. Data Analysis

MetS risk factors were categorized as positive or negative for each subject in the study. Cutoff points for each risk factor were determined based on the IDF definition of MetS for children and adolescents age 10-16. [1] Children with abdominal obesity and two other metabolic risk factors were classified as meeting the IDF definition of metabolic syndrome. Mean pedometer step counts were calculated for each participant. Independent sample t-tests were used to compare step counts and metabolic risk factors by gender. Pearson correlation coefficients were calculated on MetS risks factors and step counts, using the winter step counts as the most comprehensive data source. One way ANOVA analyzed the effect of the day of the week, with Tukey's procedure used in post hoc testing. Independent sample t-tests were used to compare step counts by gender, paired t-tests compared December and April step counts.

3. Results

Study 1

Table 1 summarizes participant demographics and results of Study 1. Of the 56 participants from the winter pedometer counts, 54 (96%) participated in CHIP. Two students (3.7%) met IDF criteria for MetS. No other risk factors for MetS were significantly related to pedometer step count.

Correlation coefficients showing associations between risk factors and winter step counts are presented in Table 2. HDL and step count were significantly associated ($p=.014$) with higher HDL levels associated with higher step counts. Boys and girls were not significantly different on risk factor levels other than in triglicerides where girls had significantly higher levels than boys ($p = .02$)

Study 2

As shown in Figure 3, boys averaged 11% higher step counts than girls in December and 15% higher count April, however the difference was not significant ($p=.168$) secondary to the small sample size. A significant difference was found between December and April pedometer step counts ($p=.00$). April was found to have a mean of 16% higher step counts than the December step counts.

There was a significant difference in pedometer step counts between Friday and Saturday as compared to Sunday, demonstrated in Figure 4 ($p< .05$). Sunday had lowest step counts for the week, with Wednesday being next lowest. In the April data, Wednesdays had the highest pedometer step counts but no day was significantly different from the others.

Table 1. Participant demographics and MetS risk factors

Variable	Boys (n=23)	Girls (n=31)	Total (n=54)	MetS Risk factor n (%)
		Mean ± SD		
Age (years)	10 ± 3	10 (3)	10 ± 3	
Triglycerides (mg/dL)	53 ± 14	75 ± 54*	64 ± 34	5 (9%)
HDL (mg/dL)	55 ± 12	56 ± 14	55 ± 13	7 (13%)
Glucose (mg/dL)	91 ± 16	89 ± 7	90 ± 11	4 (7%)
Systolic BP (mmHg)	111 ± 7	112 ± 6	111 ± 7	9 (17%)
Diastolic BP (mmHg)	63 ± 5	63 ± 5	63 ± 5	9 (17%)
Waist (cm)	73 ± 14	70 ± 9	71 ± 12	9 (17%)
	n (%)	n (%)	n (%)	
>1 MetS risk factor	10 (43%)	21 (68%)	57%)	

* Significant difference between boys and girls at p<.05
MetS, Metabolic Syndrome.

Table 2. Pearson correlation coefficients for risk factors and winter step count

Variable	Triglycerides	Glucose	HDL	Systolic	Diastolic	Waist	Winter count
Triglycerides	-	-	-	-	-	-	-
Glucose	.123	-	-	-	-	-	-
HDL	-.522*	-.316**	-	-	-	-	-
Systolic	.252	.190	-.083	-	-	-	-
Diastolic	.224	.111	-.145	.460*	-	-	-
Waist	.105	-.088	.086	.112	.168	-	-
Winter count	-.212	-.188	.356**	-.153	-.257	-.026	-

* Correlations significant at the 0.05 level (2-tailed).
** Correlations significant at the 0.01 level (2-tailed).

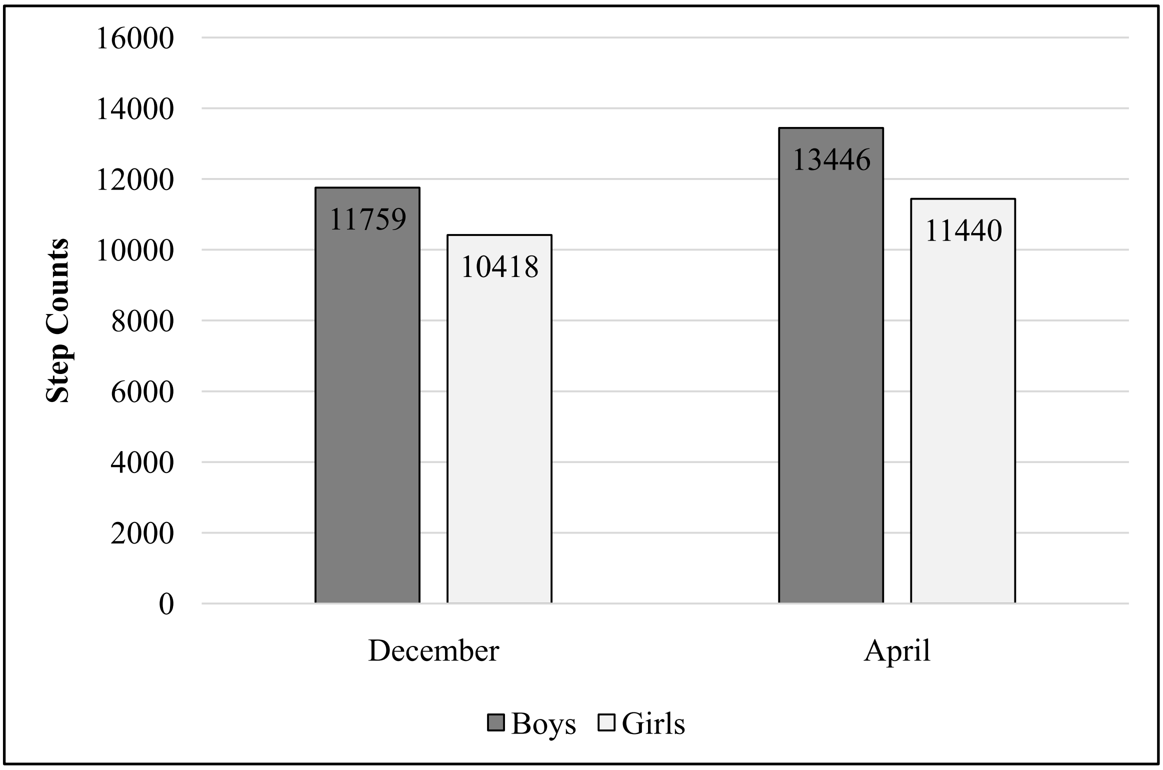

Figure 3. Seasonal comparison of mean step counts by gender

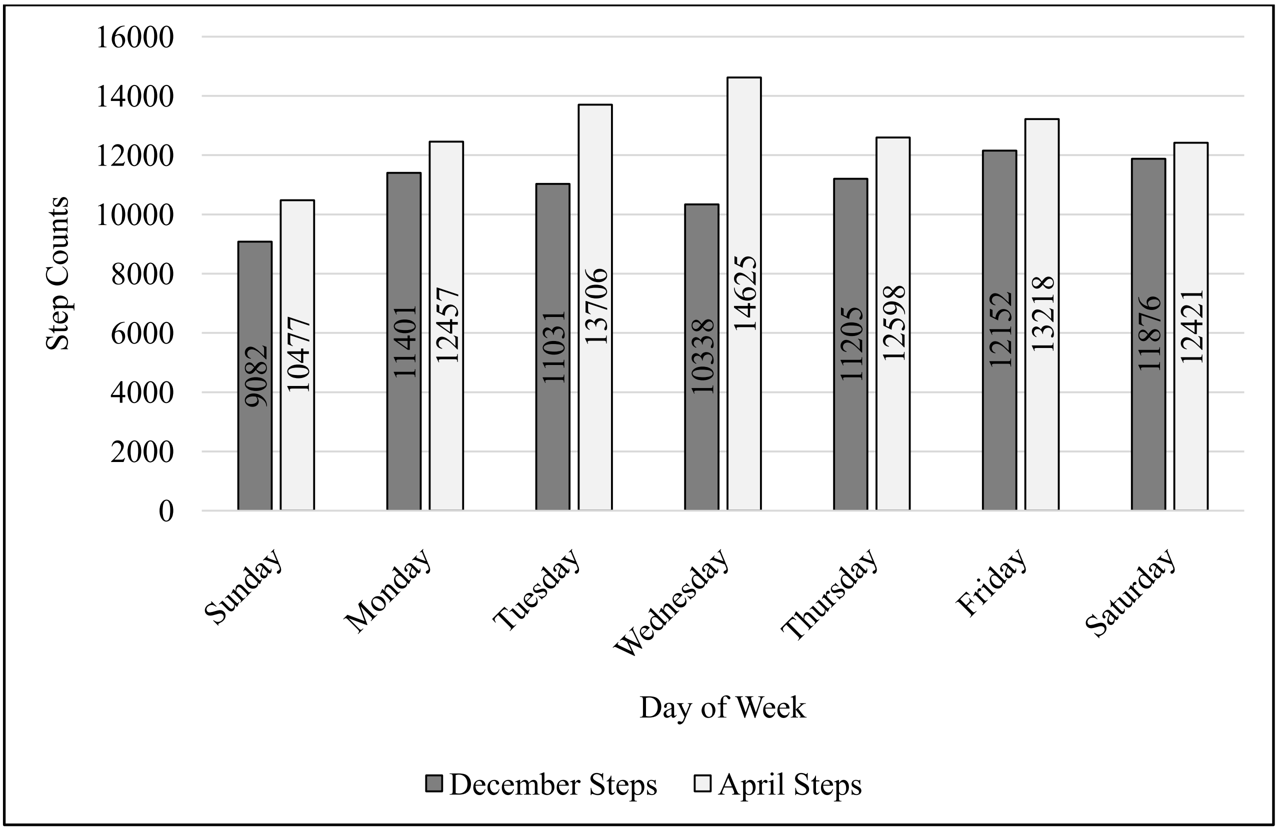

Figure 4. Mean step count variation by day and season

4. Discussion

The first part of our study looked at pedometer step count and its relation to risk factors for metabolic syndrome using data gathered by the CHIP program in children in rural Michigan. We had hypothesized that lower step counts would be associated with increased numbers of metabolic risk factors. However, the total number of metabolic risk factors did not correlate significantly with step counts and while participants with 1 or more risk factors had lower step counts than participants with no risk factors, this difference was not significant. The only statistically significant finding was that HDL levels below 40 mg/dL were correlated with a lower step count. This finding is consistent with current research as HDL levels respond positively to exercise. [45]

Of the 54 participants in Study 1, only 2 participants (3.7%) met IDF criteria for MetS, which is very close to the national average of 3.3%. [17] Although our sample size was small, our findings of MetS diagnoses from this rural community are only slightly higher than in national data sets. Larger studies, or pooling of multiple smaller studies, would be needed to determine whether our slightly higher level of MetS is significant.

The second part of this study evaluated pedometer step count and its relation to gender, season, and days of the week, with the hypotheses that boys would have higher step counts than girls, that higher step counts would be seen in April than in December, and that the weekend days would have higher step counts than weekdays. We did not find any significant difference between the boys and girls in our study, although boys did have a total of more steps than girls. This result is not typical of the population; several studies report that boys take significantly more steps/day than their female counterparts. [36,46,47] Our sample used one small community, offering participation to all the students in each of the three classrooms. A power analysis suggests that in a larger study, involving about 100 students, the differences we found would have been significant.

There was considerable inter-participant variation between genders, but in our studies, the mean step counts did not reach the levels recommended for 6 – 12 year olds, which are 15,000 steps for boys and 12,000 for boys. [42]

There was a significant difference between winter and spring step counts (p=.00). This may be explained by the large seasonal variation in Michigan. December in the Midwest is usually cold and snowy, which usually translates to less physical activity taking place outside. [48]

Although there was no significant difference between the weekend days and the weekdays for pedometer step counts, we did find in the December data that Sunday had significantly lower step counts compared to the other weekend days, Friday and Saturday. Other studies have reported fewer steps taken during the weekend days compared to weekdays, [29,30,32] but have not discussed the differences within the weekend days.

The results also showed that Wednesday was the day with the highest pedometer step counts in April, while in December it was the second lowest day. Examination of the activity reports turned in with the step counts was not able to explain these differences. The schools were contacted to determine if a change had been made to the schedule or if any other activities, such as gym class, had changed days between the data collection periods and would have contributed to the difference. Again no explanation was found.

5. Limitations

One limitation is the small sample size. This was partly because of the rural environment. Although all eligible participants in both community schools were offered participation, the small community size prevented having a larger sample. Those interested in studying such rural areas may need to collaborate and pool material from multiple communities with similar profiles to strengthen conclusion.

Unfortunately, the sample population may not be a complete representation of the children living in the rural area studied. In order to allow students to participate, both CHIP and the pedometer step count study required consent from a parent or legal guardian. The children not allowed to participate are potentially those less involved in the community, both socially and physically, and may differ in their risk profile from those allowed to participate.

Pedometers have been proven to be valid in assessing total physical activity in children, [39,49,50] however pedometers do have limitations. They can track activity but not intensity, and for some activities may underestimate steps. [29,39,51] For example the accuracy of pedometer counts varies for the actions walking, skipping, galloping, and sliding, which are common for children, especially during a physical education class. [51] This study found that pedometers are accurate for measuring steps during walking and hopping, but underestimate steps during skipping, galloping, and sliding. [51] Accelerometry may be a more accurate way of measuring the intensity and varied movement of children.

6. Conclusions

Although our first study did not find significant results between metabolic syndrome and step counts, physical activity and childhood health are closely related. Childhood health sets the foundation for a lifetime of healthy behaviors. In the children in study 1, higher levels of activity were associate with a lower risk of having a HDL level metabolic syndrome risk factor. Our finding supports the idea of higher activity levels being associated with improved cardiovascular health.

In Study 2, there was a significant difference in step counts between December and April. In the Midwest, winter makes it challenging to participate in outdoor activities. Despite the cold weather, schools should place priority on increasing the activity of students and encourage participation in gym, recess, or other physical activities. Our sample group of rural children did not meet the recommended levels of steps per day, which also demonstrates the need for rural communities to encourage play, sports, and activity to promote a healthier lifestyle.

7. Implications for School Health

This study shows that on average middle school children in rural areas are not achieving the recommended number of steps per day. Physical activity is important in children to maintain a healthy weight and to decrease their current and future health risks. Our rural population had MetS prevalence near national averages, which supports the need for programming and interventions targeting rural children. Future studies in this area should use techniques to obtain a larger sample size, should explore the use of accelerometers to monitor physical activity, and consider the use of pedometers or accelerometers for interventions and motivation for exercise adherence in middle school children. Identifying children with an increased number of MetS risk factors can help target interventions and increase health and wellness in the future for individuals as well as populations.

Human Subjects Approval Statement

This project was approved by the Institutional Review Board of Central Michigan University.

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