Received: 15 February 2025/ Revised: 17 March 2025/ Accepted: 07 April 2025

ORIGINAL ARTICLE

Journal of Hacettepe University Physical Therapy and Rehabilitation

The Relationship Between Arterial Stiffness, Hand Grip Strength, Sedentary Behavior, and Physical Activity in Adolescents with Primary Hypertension

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ABSTRACT

Purpose: This study was aim to investigate the associations between pulse wave velocity (PWV) and hand grip strength, as well as the relationships between weekday and weekend sitting time and physical activity levels on adolescent patients with primary hypertension.

Method: The study included 35 stable outpatients aged 10-19 years with primary hypertension. Demographic characteristics, physical and clinical conditions were recorded. Anthropometric measurements was taken. Hand grip strength assessed using a hand dynamometer, arterial stiffness measurement using a Holter-Ambulatory Blood Pressure Monitor (ABPM). Physical activity barriers were assessed using the Physical Activity Barriers Scale, and physical activity level with the Child Physical Activity Questionnaire (PAQ-C). Physical inactivity and inactivity levels were recorded.

Results: No significant relationship was found between dominant hand grip strength percentage and PWV values. A weak to moderate positive correlation was observed between dominant hand grip strength and PWV ($r=0.423$, $p=0.022$). A weak to moderate positive correlation was found between PWV and physical activity levels, and average weekly sitting and screen time ($r=0.375$, $p=0.045$, $r=0.397$, $p=0.033$, respectively). No significant relationship was found between PWV values and the Physical Activity Barriers Scale ($p>0.05$).

Conclusion: There is a moderate to weak relationship between handgrip strength, physical inactivity and sedentary behavior and PWV. There is no significant relationship between physical activity barriers and PWV. Future interventions should prioritize strategies to increase physical activity and reduce sedentary behavior to improve arterial health and overall cardiovascular outcomes in adolescents with hypertension.

Key Words: Primary Hypertension, Adolescence, Physical Activity, Sedantary Behaviour, Physical Activity Barriers

INTRODUCTION

Hypertension is the most significant modifiable risk factor for cardiovascular disease and all-cause morbidity and mortality (1). Globally, the prevalence of hypertension increased between 1990 and 2019, yet only half of those affected received a diagnosis, and only 25% of those patients received adequate treatment for their disease (2). Evidence suggests adult cardiovascular events and cardiovascular disease biomarkers (3). In many countries, children and adolescents exhibit elevated blood pressure (BP) at a significant rate. Primary hypertension, which is more common in children and

adolescents, is present in between 50% and 90% of cases (4). This is primarily attributed to the increased prevalence of various modifiable risk factors for hypertension in many populations worldwide, including obesity, unhealthy diets, tobacco use, and physical inactivity (5).

Arterial stiffness, particularly in the larger central arteries such as aorta, is a major contributor to coronary heart disease, strokes, cardiovascular disease (CVD), hypertension, and mortality (6, 7). Research using mice models demonstrates that hypertension contributes to hemodynamic overload, which in turn drives vascular structural remodeling. This involves processes such as vascular damage, elastin fragmentation, and extracellular matrix modifications (8). Arterial stiffness develops through various mechanisms, including because of unhealthy lifestyle factors such as smoking, poor diet, and physical inactivity, as well as a natural physiological consequence of aging (6). To mitigate diseases associated with arterial stiffness, preventive measures have been implemented or recommended, primarily based on studies of middle-aged and older adults (9). However, the relationship between hypertension and arterial stiffness in young adults and adolescents remains poorly understood (10).

Regardless of age or medical condition, muscle strength, which is positively correlated with cardiorespiratory fitness, is considered a crucial component of physical fitness linked to health (11, 12). Handgrip strength (HGS) is a commonly used method for assessing muscle strength in clinical research and physical fitness evaluations. Higher HGS has been associated with improved bone health indicators and pulmonary function in adolescents, while adolescents with low HGS are more susceptible to developing cardiometabolic diseases (13). A literature review revealed no studies investigating the relationship between handgrip strength and arterial stiffness in adolescent hypertensive patients.

Physical activity is characterized by its form, frequency, intensity, duration, and application. It is defined as any bodily movement produced by skeletal muscle contraction that increases energy expenditure above the resting metabolic rate. Physical inactivity is defined as the state in which no movement occurs (14). In pediatric populations, sedentary behavior has been identified as a significant predictor of cardiovascular health. This type of behavior encompasses spending a high number of hours engaged in low-energy-expenditure activities throughout the day, such as watching television, using a computer, or playing video games, and may contribute to elevated BP levels (15). Physical inactivity and high levels of sedentary behavior together are responsible for approximately 13% of all-cause mortality (16). The World Health Organization (WHO) recommends that children and adolescents engage in at least 60 minutes of moderate-to-vigorous-intensity physical activity per day, particularly aerobic activity, on average throughout the week (17). Approximately 80% of adolescents are insufficiently active, spending significant time on activities such as writing and seren time, which increases their risk of elevated BP (18, 19). According to Carvalho et al., playing video games and watching television increases systolic blood pressure (SBP) and diastolic blood pressure (DBP) levels. Furthermore, when combined with obesity, these factors significantly increased the risk of hypertension in children (19). Regular physical activity promotes healthy aging and growth while also preventing numerous chronic diseases (14). A large-scale study conducted in 2019 examined the physical activity levels and vascular phenotypes of children aged 6-8. This study found that children with higher levels of physical activity exhibited lower arterial stiffness (20). A review of the literature reveals a lack of studies explicitly investigating the relationship between physical activity levels, sedentary behavior, and arterial stiffness.

In summary, hypertension is becoming more common worldwide and is still a significant, controllable risk factor for cardiovascular disease. Because childhood hypertension is associated with long-term cardiovascular problems and because its main causes—obesity, poor food, tobacco use, and physical inactivity—are on the rise in young people, it is especially worrying about it. Although potentially dangerous lifestyle choices and hypertension both affect arterial stiffness, a major predictor of cardiovascular health, little is known about how arterial stiffness and hypertension in adolescents relate to one another. Although studies have linked muscle strength, especially handgrip strength (HGS), to better health outcomes, no one have specifically looked at

how it relates to arterial stiffness in adolescents with hypertension. Similarly to this, excessive sedentary behavior and physical inactivity are major contributors to high blood pressure and cardiovascular risk; yet there is not enough evidence that directly links these factors to arterial stiffness in younger groups. More research is required for understanding these associations in adolescents, as regular physical exercise is crucial to improving cardiovascular health and reducing arterial stiffness. Specific interventions that address modifiable risk factors early in life may be essential in reducing the risk of cardiovascular disease in the decades to come.

This study aims to investigate the associations between pulse wave velocity (PWV), a key indicator of arterial stiffness, and handgrip strength, as well as examine the relationships between sedentary behavior—specifically weekday and weekend sitting time duration—and physical activity levels in adolescents with primary hypertension. To support the idea that modifiable lifestyle factors are important for the vascular health of hypertensive adolescents, this study aims to investigate these interactions and figure out whether decreased muscle strength and increased sedentary behavior contribute to greater arterial stiffness in this population.

METHODS

Study Design

This cross-sectional descriptive study was conducted between May 2022 and May 2023 with the approval of Hacettepe University Non-Invasive Clinical Research Ethics Committee with the approval number GO 22/505. This study was performed according to the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. In this study, we retrospectively analyzed the medical information regarding the routine assessments of children with BPBI who applied for medical follow-up and treatment between the years 2019 to 2024.

Patients

This study included 35 stable primary hypertensive patients (two of the participants had elevated hypertension, 10 had stage 1 hypertension, and 9 had stage 2 hypertension. Information could not be obtained for 6 participants, and the blood pressure of 8 participants was normal (with medication) aged 10-19 years. These patients were outpatients followed up at the pediatric nephrology departments of Gazi University, Osmangazi University, and Eskişehir City Hospital, and they met the inclusion criteria. Individuals with any neurological or advanced orthopedic problems, acute infections, malignancies, or those who could not cooperate with the measurements were excluded from the study. Written informed consent was obtained from each patient and their families before they participated in this study.

Assessments

Demographic and Clinical Information

Patients' demographics (age, sex) and physical (height, etc.) and clinical characteristics (systolic and diastolic BP, diagnosis period, birth weight, number of medications, etc.) were assessed and collected using a standardized data form.

Anthropometric Measurement

Anthropometric measurements were obtained using a Xiaomi Body Composition Scale II (Xiaomi Mi Body Composition Scale 2, Xiaomi Corporation, Beijing, China). A total of seven parameters were assessed: body weight, muscle mass, body mass index (BMI), body fat percentage, basal metabolic rate, visceral fat, and bone mass.

Arterial stiffness

Arterial stiffness was assessed using the pulse wave velocity technique with a blood pressure holter-ABPM (Mobil-O-Graph, I.E.M., Stolberg, Germany). The measurement was performed on the non-dominant arm using an appropriate cuff size determined based on arm diameter. Participants' stroke volume, cardiac output, peripheral resistance, augmentation index, pulse wave velocity, and other relevant parameters were recorded. The average of two consecutive measurements taken 30 seconds apart was recorded (21).

Hand Grip Strength

Hand grip strength was measured using a hand dynamometer (Jamar, Sammons Preston, Rolyon, Bolingbrook, IL). Measurements were taken following standard procedures on the dominant hand. With the arm at the side of the body, the elbow flexed at 90 degrees, and the forearm and wrist in a

neutral position, the highest of three measurements was recorded as the hand grip strength (22,23).

Physical Inactivity and Sedentary Level

The scale used to assess physical activity was the Child Physical Activity Questionnaire (PAQ-C), developed by Kowalski and colleagues. This is a seven-day self-reported recall scale designed to assess moderate-intensity physical activity in children. The PAQ-C is designed for administration throughout the school year. It has two sub-dimensions: physical activities done "outside the school" and physical activities done "inside the school". The questionnaire has been validated in Turkish (22). Participants' sedentary behaviors were recorded by directly asking them about their screen time and sitting time on weekdays and weekends.

Physical Activity Barriers Scale

This scale comprises three questionnaires:

A) Children's Physical Activity Expectations Scale

The scale is a three-item Likert-type scale consisting of 17 items and two dimensions. These dimensions are negative outcome expectation sub-dimension and positive outcome expectation sub-dimension. Higher scores indicate greater expectations for both positive and negative outcomes.

B) Children's Perception of Family Support for Physical Activity Scale

This is a 5-item Likert-type scale. Scores range from 5 to 15, with higher scores indicating greater perceived family support for physical activity.

C) Parents' Physical Activity Barriers Scale

The scale includes 11 items and two dimensions. The sub-dimensions are environmental barriers and personal barriers. Separate total scores are obtained for each sub-dimension. Scores for "Environmental Barriers" range from 6 to 30, and scores for "Personal Barriers" range from 5 to 25. Higher scores in each sub-dimension indicate greater perceived barriers to physical activity in those respective areas. The validity and reliability of these questionnaires have been established in Turkish (23).

Table 1. Demographic and Clinical Characteristics of Primary Hypertension Patients (n=35)

Gender	
Female/Male (n, %)	6 (17.1)/29 (82.9)
	Mean±SD
Age (years)	15.8 (10.0-18.0)*
Height (cm)	167.97±11.14
Weight (kg)	83.24±23.69
Body Mass Index (kg/m^2)	29.17±6.46
Height z score	0.49±1.21
Weight z score	2.03±1.70
BMI z score	1.79±1.34

*Median (interquartile range), BMI Body Mass Index

Statistical Analysis

IBM SPSS Statistics for Windows, v. 26.0 (Armonk, IBM, NY, USA) was used for statistical analyses. For descriptive statistics, mean and standard deviation or median (minimum-maximum) values were given for numerical data, and frequency and percentage values were given for categorical data. Graphical methods (QQ plot, histogram, etc.) and hypothesis tests (Shapiro Wilk test) were used for normality assumption. Pearson or Spearman correlation coefficients were used to examine the relationship between numerical variables, depending on whether the assumptions were met. For relationship interpretation, $r \leq 0.30$ was interpreted as a negligible relationship, $0.31<r<0.50$ as a low, $0.51<r<0.70$ as a moderate, $0.71<r<0.90$ as a strong, and $r > 0.91$ as a very strong relationship. The significance level was taken as $p<0.05$. As a result of the pilot study, it was calculated that at least 33 cases were required to test whether the correlation coefficient was higher than 0.45, assuming 5% type I error and 20% type II error.

RESULTS

In the sample of 35 primary HT patients, the proportion of females was 17.1%. The mean age and BMI values of the patients were 15.8 (10.0-18.0) years, and BMI was 29.17±6.46 kg/m2, respectively. 91.4% of the study participants were right-handed, and 54.3% had a family history. The rate of premature birth was 28.6%. The distribution of demographic and clinical characteristics of the patients is given in Table 1.

Table 2. Hand Grip Strength, Arterial Stiffness, Physical Inactivity and Sedentary Level, Physical Activity Barriers Scales and Physical Activity Level Scores of Adolescence Primary Hypertension Patients.

	Mean±SD
Hand Grip Strength	
Dominant Hand Grip Strength (kgf)	40.51±11.53
Dominant Grip Strength Percentage (%)	123.75±23.06
Arterial Stiffness	
Pulse Wave Velocity (m/s)	5.06±0.66
Physical Inactivity and Sedentary Level	
Weekday Sitting Time (hr/day)	7.89±2.67
Weekend Sitting Time (hr/day)	7.34±2.45
Weekday Screen Time (hr/day)	4.0 (1.0–12.0)*
Weekend Screen Time (hr/day)	5.09±2.41
Average Weekly Sitting Time (hr/day)	7.61±1.98
Average Weekly Screen Time (hr/day)	4.84±2.17
Children's Expectations about Physical Activity Scale	
Positive Expectations	9.0 (8.0–16.0)*
Negative Expectations	21.86±2.86
Perception of Family Support	11.06±1.91
Physical Activity Barriers Scale for Parents	
Environmental Barriers	10.0 (5.0–21.0)*
Personal Barriers	11.0 (5.0–25.0)*
Physical Activity Level	
Child Physical Activity	2.49±0.70
Physical Activity inside school	2.84±0.87
Physical Activity Outside School	2.27±0.75

*Median (interquartile range)

Hand Grip Strength, arterial stiffness, physical inactivity and sedentary level, physical activity barriers scales, and physical activity level scores are given in Table 2. Dominant hand grip strength was given as 40.51±11.53 kg, pulse wave velocity was given as 5.06±0.66 m/s, and average weekly sitting duration was given as 7.61±1.98 hours. Physical activity levels of the patients were given as 2.49±0.70.

The relationship between PWV and hand grip strength is presented in Table 3. No significant relationship was found between the percentage of dominant hand grip strength and PWV. A low to moderate positive relationship was observed between dominant hand grip strength (measured in absolute terms) and PWV. Regarding the relationship between PWV and physical activity levels, a weak to moderate positive correlation was found between PWV and the average weekly time spent sitting and screen time. No significant correlations were observed between PWV values and children's expectations regarding physical activity, perceived family support for physical activity, parental perceptions of physical activity barriers, or physical activity scale scores ($p>0.05$).

DISCUSSION

This study investigated the relationship between PWV, a measure of arterial stiffness, and hand grip strength, sedentary behavior, perceived barriers to physical activity, and physical activity levels in adolescents with primary hypertension. Our results revealed a weak to moderate positive correlation between PWV and hand grip strength, as well as with sedentary behavior (average weekly sitting and screen time). No significant relationship was found between PWV and either perceived barriers to physical activity or overall physical activity levels.

Low muscular strength, as assessed by hand grip dynamometry, is associated with increased morbidity and mortality in adulthood and is a recognized indicator of poor health during adolescence. Muscle strength is included in many current recommendations for maintaining and improving health and for preventing chronic diseases (24). Adolescents with higher muscle strength have a lower (20–35%) risk of premature death from all causes, including cardiovascular disease (25). Arterial stiffness is increasingly recognized as an early indicator of cardiovascular disease in children and adolescents (26). Furthermore, increased arterial stiffness itself elevates the risk of sudden cardiovascular events and cardiovascular mortality (27). Previous studies in individuals over 40 have demonstrated a link between arterial stiffness and HGS (28, 29). The Wakayama Study showed that HGS decreased with increasing brachial-ankle PWV after controlling for confounding variables such as sex, age, and systolic blood pressure. This suggests that the increase in arterial stiffness may be related to a decrease in muscle strength (30). Our study in adolescents with hypertension found a weak to moderate positive correlation between PWV and dominant hand grip strength. These findings suggest that endothelial dysfunction may begin at an early age.

Research on adolescents has shown a link between sedentary lifestyles, low physical activity levels, and adverse cardiovascular health outcomes, including high blood pressure, obesity, and impaired arterial health (31-34). Low

Table 3. Correlation in the Hand Grip Strength, Physical Inactivity and Sedentary Level, Physical Activity Barriers Scales, Physical Activity Level Scores and Arterial Stiffness in Primary Hypertension Patients

	Pulse Wave Velocity	
	r	(p)
Hand Grip Strength		
Dominant Hand Grip Strength (kgf)	0.423	(0.022)
Dominant Grip Strength Percentage (%)	0.278	(0.144)
Physical Inactivity and Sedentary Level		
Average Weekly Sitting Time (hr/day)	0.375	(0.045)
Average Weekly Screen Time (hr/day)	0.397	(0.033)
Children's Expectations about Physical Activity Scale		
Positive Expectations	-0.084	(0.665)
Negative Expectations	-0.019	(0.921)
Perception of Family Support	-0.127	(0.512)
Physical Activity Barriers Scale for Parents		
Environmental Barriers	-0.147	(0.448)
Personal Barriers	-0.241	(0.208)
Physical Activity Scale		
Child Physical Activity	-0.185	(0.337)
Physical Activity at school	-0.214	(0.264)
Physical Activity Outside School	-0.170	(0.338)

physical activity levels at age 18 increase the risk of hypertension by 4%, and a decrease of 1 unit of physical activity per year increases the risk by 2% per year (32). A study by Ding et al. found that physically active individuals (59.2%) had a significantly decreased risk of obesity compared to those with low activity levels. Moreover, each additional hour of sedentary behavior increased the BMI z-score by 0.015 units (p=0.004) (31). A 2012 study demonstrated that physical activity positively and independently impacts arterial stiffness in adolescents. Increased physical activity is associated with greater improvements in arterial stiffness, particularly in adolescents with diabetes and obesity, emphasizing the significant impact of physical activity on arterial health beyond energy balance (34). Marshall et al. concluded that the relationship between physical activity and vascular health in children is complex and that moderate-to-vigorous physical activity must be performed in sufficient doses to significantly affect vascular stiffness (33). Our study found no significant relationship between physical activity levels (assessed both within and outside of school) and PWV in hypertensive adolescents. A weak to moderate correlation was observed between physical inactivity/sedentary behavior and PWV.

Regularly increasing physical activity can reduce cardiovascular risk and lower blood pressure. However, substantial barriers prevent young people from engaging in sufficient physical activity (35). These barriers include internal factors such as lack of motivation, lack of interest, and increased screen time, and external factors such as a lack of safe play areas, limited access to appropriate sports facilities, lack of time, and lack of parental support, all of which significantly reduce the likelihood of regular physical activity (36). A 2024 study of healthy adolescents aged 11-16, using a 5-point Likert scale, found that external barriers were more prominent than internal barriers. he most frequently reported external barriers were "lack of resources" (lack of fitness centers, mean = 3.49) and "lack of encouragement from family or friends." The most significant internal barriers were "lack of self-confidence" (mean = 3.47) and "not recognizing the positive effects of exercise on health" (37). A systematic review by Zelenovic & Manić et al., including 11 studies published between 2003 and 2020 with a total of 6,683 participants, identified a lack of time as the most common external barrier. Many participants cited school obligations and other responsibilities as reasons for not having enough time for physical activity. Lack of support from family and friends was also a significant barrier, reported by 36.8% to 75.8% of participants in the included studies. Lack of motivation, concerns about appearance during exercise, and lack of energy were common barriers for female participants, while lack of time and lack of access to sports facilities were more common barriers for males (38). Our study found no significant relationship between PWV and children's expectations about physical activity (both positive and negative), perceived family support, or parental perceptions of physical activity barriers (both environmental and personal) in hypertensive adolescents.

Limitations

This study has some limitations. One limitation of our study is that due to the unequal number of male and female participants, the relationships between male and female groups could not be clearly determined**.** There is a lack of longitudinal data. In addition, individuals' physical activity and physical inactivity and sedentary level could not be assessed objectively.

CONCLUSION

This study highlights the complex interplay between hand-grip strength, sedentary behavior, arterial stiffness, and physical activity levels in adolescents with hypertension. The weak to moderate positive correlation between PWV and hand-grip strength suggests that arterial stiffness and endothelial dysfunction may begin early in life. However, PWV did not significantly correlate with physical activity levels or perceived barriers to physical activity. Our findings emphasize the importance of addressing sedentary behaviors and promoting muscle strength to reduce cardiovascular risk in this population. While perceived barriers to physical activity are known to influence participation, they did not significantly impact arterial stiffness in our study sample. Future interventions should develop strategies to increase daily mobility, prioritize strategies to increase physical activity, and reduce sedentary behavior to improve arterial health and overall cardiovascular outcomes in adolescents with hypertension.

Acknowledgments

This study was conducted as part of the first author's doctoral thesis.

Author Contributions: All authors contributed to the study concept. Study design: Melda SAĞLAM and Emine Burcu ÖZCAN. Referral of eligible patients to our study: Sevcan A. BAKKALOĞLU, Bahar BÜYÜKKARAGÖZ, Aslı KAVAZ TUFAN, Yeşim ÖZDEMİR ATİKEL, Emre LEVENTOĞLU, Şule PEKTAŞ LEBLEBİCİER, Bahruz HÜSEYNLİ, data collection: Emine Burcu ÖZCAN, data analysis: Merve BAŞOL GÖKSÜLÜK and Melda SAĞLAM. The first draft of the article was written. Melda SAĞLAM and Naciye VARDAR YAĞLI provided their comments. All the authors provided comments and then read and approved of the final manuscript.

Financial Support: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Conflict of Interest: The author(s) states that there are no potential conflicts of interest concerning the research, writing, and/or publication of this article.

Ethical approval: This descriptive cross-sectional research was carried out between May 2022 and May 2023 following the approval of the Hacettepe University Non-Invasive Clinical Research Ethics Committee (approval no: GO 22/505).

How to cite this article: Özcan E. B, Vardar Yağlı N, Bakkaloğlu SA, Büyükkaragöz B, Kavaz Tufan A, Özdemir Atikel Y, Pektaş Leblebicier Ş, Leventoğlu E, Hüseynli B, Başol Göksülük M, Sağlam M. The Relationship Between Arterial Stiffness, Hand Grip Strength, Sedentary Behavior, and Physical Activity in Adolescents with Primary Hypertension. Journal of Hacettepe University Physical Therapy and Rehabilitation. 2025;3(3): 100-108

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