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# The Buffering Role of Physical Activity in the Impact of Sedentary Behavior on Lipid Metabolism

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**Abstract**

Sedentary behavior, characterized by prolonged periods of inactivity, has become increasingly prevalent in modern society, contributing significantly to adverse lipid metabolism and associated cardiovascular risks. Physical activity, recognized for its beneficial effects on metabolic health, plays a critical role in mitigating these negative impacts. This integrative review explores the buffering role of physical activity in counteracting the effects of sedentary behavior on lipid metabolism. Through an analysis of recent studies, we examine the mechanisms by which physical activity improves lipid profiles, including enhanced lipoprotein lipase activity, improved insulin sensitivity, and upregulation of genes involved in lipid metabolism. The review also highlights the contextual variability of these effects, emphasizing how factors such as obesity, age, metabolic conditions, socioeconomic status, and genetic predispositions influence the efficacy of physical activity as a protective measure. The findings underscore the necessity for personalized and context-specific public health strategies to promote physical activity and reduce sedentary time, thereby improving metabolic health and reducing the burden of cardiovascular diseases.

**Keywords:** sedentary behavior, physical activity, lipid metabolism, obesity, metabolic syndrome

## 1. Introduction

Sedentary behavior, typified by prolonged periods of sitting or physical inactivity, has emerged as a significant public health concern in contemporary society, particularly as technological advancements and lifestyle changes have led to increased sedentary lifestyles. This behavior is intricately linked to a range of adverse health outcomes, with one of the most critical being its impact on lipid metabolism. Lipid metabolism, which includes the synthesis and breakdown of lipids in the body, plays a crucial role in maintaining cardiovascular health and overall metabolic function. When disrupted, it can lead to dyslipidemia, a condition characterized by abnormal levels of lipids in the blood, such as elevated triglycerides (TG), low-density lipoproteins (LDL), and reduced high-density lipoproteins (HDL). These lipid abnormalities are well-established risk factors for cardiovascular diseases, which remain the leading cause of mortality globally.

The increasing prevalence of sedentary behavior has coincided with rising rates of obesity, metabolic syndrome, and cardiovascular diseases, suggesting a strong link between these lifestyle factors and lipid dysregulation.

Research has consistently demonstrated that prolonged sedentary time is associated with unfavorable lipid profiles, including higher levels of TG, LDL, and total cholesterol (TC), alongside reduced levels of HDL. These findings are concerning given the central role of lipid metabolism in the pathogenesis of atherosclerosis and other cardiovascular conditions.

Conversely, physical activity is widely recognized for its beneficial effects on metabolic health. Engaging in regular physical activity, particularly at moderate to vigorous intensities, has been shown to improve lipid profiles by increasing HDL levels and reducing TG and LDL levels. Physical activity facilitates lipid metabolism by enhancing lipoprotein lipase activity, which plays a key role in the hydrolysis of triglycerides in lipoproteins, and by increasing the catabolism of LDL particles. Physical activity can modulate the expression of genes involved in lipid metabolism, further contributing to its lipid-lowering effects.

Given these contrasting effects of sedentary behavior and physical activity, the concept of physical activity serving as a buffer against the negative impacts of sedentary behavior on lipid metabolism has gained attention in recent years. This integrative review aims to explore this buffering role, examining how different intensities and types of physical activity might mitigate the adverse effects of prolonged sedentary time on lipid metabolism. It will also consider the variability of these effects across different populations, including variations by age, sex, and baseline metabolic health status. By synthesizing evidence from recent studies, this review seeks to provide a comprehensive understanding of the interplay between sedentary behavior, physical activity, and lipid metabolism, and to offer insights into how public health interventions might be designed to optimize metabolic health through targeted physical activity recommendations.

## 2. The Impact of Sedentary Behavior on Lipid Metabolism

Sedentary behavior, defined as any waking activity characterized by an energy expenditure of ≤1.5 metabolic equivalents (METs) while in a sitting or reclining posture, has become increasingly prevalent in modern societies. This rise in sedentary behavior is largely attributable to changes in work environments, increased screen time, and the convenience of technology, which collectively encourage prolonged periods of inactivity. The health implications of such a lifestyle are profound, particularly concerning lipid metabolism—a critical process involving the synthesis, transport, and degradation of lipids in the body. Abnormalities in lipid metabolism are closely linked to the development of cardiovascular diseases (CVD), which remain the leading cause of morbidity and mortality worldwide.

A substantial body of research has established a strong association between sedentary behavior and adverse lipid profiles. These unfavorable changes include elevated levels of triglycerides (TG), total cholesterol (TC), and low-density lipoproteins (LDL), alongside reduced levels of high-density lipoproteins (HDL). Each of these lipid parameters plays a crucial role in cardiovascular health, with elevated TG and LDL levels being particularly detrimental due to their involvement in the formation of atherosclerotic plaques, which can lead to coronary artery disease, stroke, and other cardiovascular events.

For instance, a study conducted by Bondge et al. (2021) in a cohort of healthy individuals found that prolonged sedentary behavior was strongly correlated with higher body mass index (BMI), TC, and LDL levels. This study highlighted that as the duration of sedentary lifestyle increases, so does the risk of dyslipidemia, characterized by these elevated lipid levels. The research also demonstrated moderate positive correlations between sedentary time and triglycerides (TG) and waist-hip ratio (WHR), further linking sedentary behavior with obesity—a key driver of metabolic syndrome and cardiovascular risk.

The mechanisms through which sedentary behavior influences lipid metabolism are multifaceted. One significant pathway involves the reduction in lipoprotein lipase (LPL) activity. LPL is an enzyme critical for the hydrolysis of triglycerides into free fatty acids and glycerol, which can be utilized or stored by the body. During prolonged periods of inactivity, LPL activity decreases, leading to impaired clearance of triglycerides from the bloodstream and resulting in hypertriglyceridemia—a condition characterized by abnormally high levels of TG in the blood. This reduction in LPL activity also contributes to a decrease in HDL levels, further exacerbating cardiovascular risk.

Sedentary behavior is associated with insulin resistance, another key factor influencing lipid metabolism. Insulin resistance, often precipitated by prolonged inactivity, impairs the ability of insulin to facilitate glucose uptake in cells, leading to higher blood glucose levels. This condition is closely linked to the development of type 2 diabetes and is associated with dyslipidemia, particularly elevated TG and reduced HDL levels. The interplay between insulin resistance and lipid metabolism creates a vicious cycle, where metabolic disturbances reinforce each other, significantly increasing the risk of cardiovascular diseases.

Sedentary behavior has been shown to induce changes in the expression of genes involved in lipid metabolism. For example, studies have found that prolonged inactivity can lead to alterations in the expression of peroxisome proliferator-activated receptor gamma (PPARγ) and sterol regulatory element-binding proteins (SREBPs), both of which are key regulators of lipid synthesis and storage. These changes can promote lipid accumulation in tissues such as the liver and adipose tissue, contributing to conditions such as non-alcoholic fatty liver disease (NAFLD) and obesity.

The relationship between sedentary behavior and lipid metabolism is also influenced by other factors such as diet, age, and genetic predisposition. For instance, individuals with a diet high in saturated fats and sugars are more likely to experience the detrimental effects of sedentary behavior on lipid metabolism, as their baseline lipid profiles are already compromised. Similarly, aging is associated with a natural decline in metabolic rate and physical activity levels, making older adults particularly vulnerable to the negative effects of prolonged sedentary time on lipid metabolism.

Sedentary behavior exerts a significant negative impact on lipid metabolism, contributing to an increased risk of cardiovascular diseases through multiple pathways, including reduced lipoprotein lipase activity, insulin resistance, and changes in gene expression related to lipid synthesis and storage. The evidence underscores the importance of mitigating sedentary behavior through lifestyle modifications, particularly increasing physical activity, to improve lipid profiles and reduce cardiovascular risk.

**3. The Buffering Role of Physical Activity**

Physical activity has long been recognized as a cornerstone of cardiovascular and metabolic health, counteracting the detrimental effects of a sedentary lifestyle. The buffering role of physical activity in mitigating the adverse impacts of sedentary behavior on lipid metabolism is particularly compelling, given the pervasive nature of sedentary habits in modern society. Through various mechanisms, physical activity influences lipid metabolism, helping to maintain or restore favorable lipid profiles even in the presence of significant sedentary behavior.

One of the primary ways in which physical activity buffers the negative effects of sedentary behavior is by enhancing the activity of lipoprotein lipase (LPL), an enzyme crucial for the breakdown of triglycerides (TG) into free fatty acids and glycerol. These metabolites can be used as energy or stored in adipose tissue, depending on the body's needs. During physical activity, LPL activity is significantly increased, particularly in skeletal muscles, leading to a more efficient clearance of TG from the bloodstream. This effect is vital for maintaining lower TG levels, even when sedentary behavior would otherwise lead to hypertriglyceridemia. Studies, such as those conducted by Crichton and Alkerwi (2015), have demonstrated that engaging in medium to high levels of physical activity can lead to a more favorable lipid profile, specifically by increasing high-density lipoprotein (HDL) levels and reducing TG levels, thereby offsetting the effects of sedentary behavior (Crichton & Alkerwi, 2015).

In addition to its effects on LPL, physical activity also modulates the expression of genes involved in lipid metabolism. Regular physical activity has been shown to upregulate the expression of peroxisome proliferator-activated receptors (PPARs), particularly PPARα and PPARγ, which are key regulators of fatty acid oxidation and lipid storage. By enhancing the expression of these receptors, physical activity promotes the utilization of fatty acids as an energy source, reducing the accumulation of lipids in the blood and tissues. This gene regulation is crucial in mitigating the effects of sedentary behavior, which is often associated with downregulation of these pathways and subsequent lipid accumulation.

Physical activity plays a crucial role in improving insulin sensitivity, which is closely linked to lipid metabolism. Insulin sensitivity refers to how effectively the body's cells respond to insulin, a hormone that regulates glucose

uptake and lipid storage. Sedentary behavior is known to impair insulin sensitivity, leading to insulin resistance—a condition that not only increases blood glucose levels but also disrupts normal lipid metabolism, resulting in elevated TG and reduced HDL levels. Regular physical activity enhances insulin sensitivity by improving glucose uptake in muscle cells and increasing glycogen storage capacity. This improvement in insulin sensitivity helps maintain a more balanced lipid profile, even in individuals who engage in significant sedentary behavior. For instance, a study by Agbaje (2023) found that increased light physical activity (LPA) had a substantial cholesterol-lowering effect, which was more resistant to the attenuating influence of fat mass compared to moderate to vigorous physical activity (MVPA) (Agbaje, 2023).

The intensity and type of physical activity also play a significant role in its buffering capacity. While moderate to vigorous physical activity (MVPA) is often highlighted for its cardiovascular benefits, research suggests that even light physical activity (LPA) can significantly mitigate the effects of sedentary behavior on lipid metabolism. For instance, light activities such as walking, standing, and even low-intensity household tasks have been shown to improve lipid profiles by increasing HDL levels and reducing LDL and TG levels. This finding is particularly important for populations that may be unable to engage in more intense forms of exercise, such as the elderly or those with certain physical limitations. The study by Strizich et al. (2018) highlighted this by showing that even modest increases in physical activity could counteract some of the negative effects of sedentary behavior on HDL-C levels in US Hispanic/Latino youth, underscoring the importance of incorporating regular movement into daily routines (Strizich et al., 2018).

The duration and frequency of physical activity are critical in determining its effectiveness as a buffer. Regular, consistent physical activity is more effective at improving lipid metabolism than sporadic, high-intensity exercise bouts. This is because sustained activity helps maintain elevated levels of beneficial enzymes and hormones that regulate lipid metabolism, while also continuously reducing the time spent in sedentary behaviors. Studies such as those by Park et al. (2020) have emphasized the importance of daily physical activity in promoting overall metabolic health, particularly in reducing the impact of sedentary time on lipid profiles (Park et al., 2020).

Another important aspect of the buffering role of physical activity is its differential impact across various populations. For example, in older adults, who may experience age-related declines in metabolic function and physical activity levels, even light to moderate physical activity has been shown to significantly improve lipid profiles and reduce the risk of cardiovascular diseases. This population-specific impact is crucial for tailoring public health recommendations to maximize the benefits of physical activity in different demographic groups.

Physical activity serves as a powerful buffer against the negative impacts of sedentary behavior on lipid metabolism. Through mechanisms such as increased LPL activity, enhanced gene expression related to lipid metabolism, improved insulin sensitivity, and the modulation of lipid profiles, regular physical activity helps maintain metabolic health even in the face of prolonged inactivity. The intensity, type, duration, and frequency of physical activity are all important factors that influence its effectiveness, making it essential to promote physical activity as a key component of public health strategies aimed at reducing the burden of sedentary lifestyles on cardiovascular health.

**4. Age and Population-Specific Considerations**

The buffering effect of physical activity on the negative consequences of sedentary behavior is not uniform across all age groups and populations. Instead, it exhibits significant variability, influenced by factors such as age, ethnicity, baseline health status, and socioeconomic background. Understanding these variations is crucial for tailoring interventions that maximize the benefits of physical activity across diverse groups.

In children and adolescents, the role of physical activity in counteracting the effects of sedentary behavior is particularly important given the increasing prevalence of sedentary lifestyles in this demographic, driven by factors such as increased screen time and changes in leisure activities. For instance, research conducted by Strizich et al. (2018) on US Hispanic/Latino youth found that higher levels of sedentary behavior were associated with lower high-density lipoprotein cholesterol (HDL-C)

levels, even after controlling for physical activity and body mass index (BMI) (Strizich et al., 2018). This finding underscores the unique metabolic vulnerability of this population, where even moderate levels of sedentary behavior can have a pronounced negative impact on lipid profiles, potentially setting the stage for future cardiovascular issues. This study highlights the need for targeted public health strategies that address both the reduction of sedentary time and the promotion of physical activity in youth, particularly in ethnic minority groups who may already be at a higher risk for metabolic disorders.

In contrast, older adults face different challenges. Age-related declines in physical function and metabolic health can make it more difficult for this population to engage in and benefit from physical activity. However, even in the presence of these challenges, physical activity remains a critical factor in maintaining health and mitigating the effects of sedentary behavior. Meneguci et al. (2021) demonstrated that in older adults, physical activity was directly associated with reduced disability in instrumental activities of daily living (IADL), such as managing finances, shopping, and preparing meals. These activities are essential for independent living, and their decline is a significant marker of reduced quality of life and increased dependency (Meneguci et al., 2021). The study also found that sedentary behavior was indirectly associated with increased IADL disability, likely mediated through its impact on physical health and functional capacity. This indicates that in older adults, physical activity not only helps to maintain lipid metabolism but also plays a crucial role in preserving functional independence and delaying the onset of disability.

The variability in the effects of physical activity and sedentary behavior across different age groups can be partly explained by differences in physiological resilience and adaptability. In younger individuals, the metabolic system is generally more adaptable and responsive to changes in activity levels. This means that while physical activity can effectively counteract the negative effects of sedentary behavior, the absence of sufficient activity can lead to rapid declines in metabolic health, as seen in the reduced HDL-C levels among sedentary youth. On the other hand, older adults, who typically have lower baseline levels of physical activity and greater metabolic inflexibility, may require more consistent and structured physical activity interventions to achieve similar protective effects. The age-related decline in muscle mass, known as sarcopenia, also plays a role in this dynamic, as reduced muscle mass is associated with impaired lipid metabolism and increased insulin resistance, further complicating the metabolic picture in the elderly.

Ethnic and racial disparities further complicate the relationship between physical activity, sedentary behavior, and lipid metabolism. For example, research has shown that African American and Hispanic populations are more likely to experience adverse lipid profiles and higher rates of metabolic syndrome compared to their Caucasian counterparts. These disparities can be attributed to a combination of genetic, environmental, and socioeconomic factors. In populations with a predisposition to metabolic disorders, the protective effects of physical activity may be less pronounced, or alternatively, the negative impacts of sedentary behavior may be more severe. Therefore, interventions in these groups may need to be more aggressive in promoting physical activity and reducing sedentary time.

Socioeconomic status (SES) is another critical factor influencing the relationship between sedentary behavior, physical activity, and lipid metabolism. Lower SES is often associated with reduced access to safe environments for physical activity, limited availability of recreational facilities, and higher levels of occupational sedentary behavior. This socioeconomic divide can exacerbate the health disparities seen in lipid metabolism and related outcomes. For instance, lower SES individuals may not only be more sedentary but also have diets higher in processed foods and lower in nutritional quality, further compounding the risk of dyslipidemia and cardiovascular diseases. In such populations, community-based interventions that increase access to physical activity opportunities and promote lifestyle changes are essential for mitigating these risks.

Gender differences also play a role in how physical activity interacts with sedentary behavior to affect lipid metabolism. Some studies suggest that women may be more susceptible to the adverse effects of sedentary behavior on lipid metabolism, particularly during postmenopausal years when estrogen levels decline, leading to unfavorable changes in

lipid profiles, such as increased LDL and reduced HDL levels. Physical activity during these years becomes even more critical as a preventive measure against the cardiovascular risks associated with menopause.

The buffering role of physical activity against the negative impacts of sedentary behavior on lipid metabolism is influenced by a complex interplay of factors including age, ethnicity, socioeconomic status, and gender. Younger populations may benefit from interventions that simultaneously reduce sedentary behavior and increase physical activity, while older adults require consistent, structured exercise programs to maintain functional independence and metabolic health. Ethnic and socioeconomic disparities necessitate tailored approaches to effectively address the unique challenges faced by these populations. Understanding these nuances is key to designing effective public health strategies that promote metabolic health across diverse demographic groups.

**5. Contextual Variations in the Buffering Role of Physical Activity**

The buffering role of physical activity in mitigating the adverse effects of sedentary behavior on lipid metabolism is well-documented, yet it is not universally effective across all populations and contexts. Several studies highlight the complexity and variability of this relationship, suggesting that the protective effects of physical activity are influenced by factors such as the intensity and frequency of activity, the specific metabolic context, underlying health conditions, and population characteristics.

One of the most significant contextual variations in the buffering role of physical activity arises in populations with obesity, particularly abdominal obesity. Abdominal obesity, characterized by excessive fat accumulation in the abdominal region, is closely linked to insulin resistance, dyslipidemia, and an increased risk of cardiovascular diseases. In this context, the typical benefits of physical activity may be attenuated or altered due to the metabolic challenges posed by excess adiposity. A study by McGuire et al. (2011) examined the effects of physical activity in adults with abdominal obesity and found that neither light physical activity (LPA) nor sporadic moderate-to-vigorous physical activity (MVPA) was significantly associated with improvements in glucose metabolism or reductions in cardiometabolic risk (McGuire et al., 2011). This finding suggests that the metabolic derangements associated with abdominal obesity, such as chronic low-grade inflammation and impaired insulin signaling, may diminish the effectiveness of physical activity in this population.

The diminished buffering effect of physical activity in the context of obesity may also be related to the intensity and duration of activity required to produce significant metabolic benefits. While light and sporadic physical activity may be sufficient to improve lipid profiles in lean or metabolically healthy individuals, those with obesity may require more sustained and intense activity to achieve comparable benefits. This is supported by research indicating that high-intensity interval training (HIIT) or prolonged aerobic exercise may be more effective in reducing visceral fat and improving insulin sensitivity in obese individuals, compared to lower-intensity activities. However, the feasibility of such intense exercise regimens in individuals with obesity, who may also suffer from joint pain, mobility issues, or other comorbidities, presents a significant challenge.

In addition to obesity, other metabolic conditions such as type 2 diabetes and metabolic syndrome can also influence the effectiveness of physical activity as a buffer against the negative effects of sedentary behavior. In individuals with type 2 diabetes, the ability of physical activity to improve lipid metabolism may be compromised by existing insulin resistance and hyperglycemia. For instance, while physical activity typically enhances lipoprotein lipase (LPL) activity and increases the clearance of triglycerides from the blood, this effect may be blunted in individuals with severe insulin resistance, where the cellular response to exercise-induced insulin signaling is impaired. This suggests that in diabetic populations, the buffering role of physical activity may need to be supplemented with other interventions, such as dietary modifications or pharmacotherapy, to achieve optimal metabolic outcomes.

The timing and pattern of physical activity relative to sedentary behavior also play a crucial role in determining its effectiveness. Research has shown that breaking up prolonged periods of sitting with short bouts of physical activity, such as standing or light walking, can

significantly improve postprandial glucose and lipid metabolism. However, in certain populations, such as those with metabolic syndrome, the frequency and intensity of these interruptions may need to be greater to achieve a meaningful impact. For example, a study by Peddie et al. (2013) found that in healthy adults, interrupting sitting time with brief walks every 30 minutes significantly reduced postprandial insulin and glucose levels, but the same effect was less pronounced in individuals with metabolic syndrome, suggesting a need for more frequent or more intense activity breaks (Peddie et al., 2013).

Another important contextual factor is the age-related decline in metabolic flexibility, which refers to the body's ability to efficiently switch between fuel sources (e.g., from carbohydrates to fats) based on availability and demand. In younger individuals, physical activity can effectively enhance metabolic flexibility, thereby improving lipid metabolism and reducing the impact of sedentary behavior. However, in older adults, particularly those with sarcopenia (age-related loss of muscle mass), the capacity for metabolic adaptation is diminished. This reduction in metabolic flexibility means that even regular physical activity may not fully counteract the negative effects of prolonged sedentary behavior on lipid metabolism in the elderly. Instead, a combination of resistance training to preserve muscle mass and aerobic exercise to enhance cardiovascular health may be necessary to maintain metabolic health in this population.

Socioeconomic factors also play a critical role in the contextual effectiveness of physical activity. Individuals from lower socioeconomic backgrounds may face barriers to engaging in regular physical activity, such as limited access to safe exercise environments, lack of time due to multiple jobs, or financial constraints that limit participation in structured exercise programs. These populations may be more likely to engage in sedentary occupations and have higher levels of stress, which can further exacerbate the negative effects of sedentary behavior on lipid metabolism. Consequently, the buffering role of physical activity in these contexts may be less pronounced, and public health interventions may need to address these broader social determinants of health to be effective.

The interaction between physical activity and sedentary behavior may also be influenced by genetic factors. Genetic predispositions to conditions such as dyslipidemia, insulin resistance, or obesity can modulate the body's response to physical activity. For example, individuals with certain genetic variants that affect lipid metabolism may experience more significant improvements in lipid profiles in response to physical activity, while others may require more intense or prolonged activity to achieve similar benefits. Understanding these genetic differences could help tailor physical activity recommendations to optimize health outcomes based on individual genetic profiles.

The buffering role of physical activity in mitigating the effects of sedentary behavior on lipid metabolism is highly context-dependent. Factors such as obesity, metabolic conditions, age, socioeconomic status, and genetics all influence the extent to which physical activity can counteract the negative impacts of sedentary behavior. These contextual variations underscore the need for personalized and context-specific approaches to promoting physical activity, particularly in populations at higher risk for metabolic and cardiovascular diseases. By recognizing and addressing these variations, public health strategies can be more effectively tailored to improve lipid metabolism and overall metabolic health across diverse populations.

## 6. Conclusion

The integration of regular physical activity into daily routines is not merely beneficial but essential in mitigating the adverse effects of sedentary behavior on lipid metabolism, a critical determinant of cardiovascular and metabolic health. As society becomes increasingly sedentary, with long hours spent in sitting or reclining postures due to modern work environments, leisure activities, and the pervasive use of technology, the importance of counterbalancing these behaviors with adequate physical activity cannot be overstated. The evidence consistently demonstrates that physical activity, even at light or moderate intensities, can significantly improve lipid profiles by enhancing the breakdown of triglycerides, increasing HDL levels, and reducing LDL levels. These changes are crucial in preventing the onset of dyslipidemia, a condition closely associated with atherosclerosis and other cardiovascular diseases. The mechanisms through which physical activity exerts these

effects are multifaceted, involving enhanced lipoprotein lipase (LPL) activity, improved insulin sensitivity, and the upregulation of genes involved in fatty acid oxidation and lipid transport. These physiological adaptations collectively help maintain a favorable balance in lipid metabolism, even in the presence of substantial sedentary behavior. However, the effectiveness of physical activity as a buffer against the negative impacts of sedentary behavior is not uniform across all populations. Contextual factors such as obesity, metabolic syndrome, age, socioeconomic status, and genetic predispositions significantly influence how well physical activity can counteract the metabolic disturbances caused by prolonged inactivity. For instance, in individuals with abdominal obesity or type 2 diabetes, the typical benefits of physical activity on lipid metabolism may be attenuated due to underlying insulin resistance and chronic inflammation. These conditions require more intense or sustained physical activity to achieve similar metabolic benefits compared to those observed in metabolically healthy individuals.

The timing, frequency, and intensity of physical activity are critical determinants of its buffering capacity. Research indicates that breaking up prolonged sitting with short, frequent bouts of physical activity can significantly improve postprandial lipid and glucose metabolism. This finding is particularly relevant in modern work environments where sedentary behavior is almost unavoidable. Interventions that encourage regular movement throughout the day, rather than relying solely on structured exercise sessions, may offer a more practical and effective approach to improving metabolic health in sedentary populations. In older adults, who experience age-related declines in muscle mass and metabolic flexibility, physical activity plays a dual role. It not only helps maintain favorable lipid profiles but also preserves functional capacity, thereby reducing the risk of disability and dependency. However, the type of physical activity recommended for older adults may need to be adjusted to include both aerobic exercises, to improve cardiovascular health, and resistance training, to combat sarcopenia and maintain muscle strength. The role of socioeconomic and environmental factors cannot be ignored. Populations with limited access to safe exercise environments, lower levels of education, or higher levels of occupational sedentary behavior are at greater risk of the adverse effects of sedentary lifestyles. Public health strategies must therefore be multifaceted, addressing not only the promotion of physical activity but also the broader social determinants of health that contribute to sedentary behavior.

Individual genetic differences may modulate the response to physical activity, making it imperative to consider personalized approaches in public health interventions. Understanding these genetic variations could lead to more targeted and effective strategies for improving lipid metabolism through physical activity, especially in high-risk populations. While the buffering role of physical activity against the negative impacts of sedentary behavior on lipid metabolism is well-supported by evidence, its effectiveness is influenced by a complex interplay of factors. This variability highlights the need for personalized, context-specific approaches in public health strategies aimed at reducing sedentary time and promoting physical activity. By tailoring interventions to the specific needs of different populations, we can more effectively combat the rising tide of metabolic disorders and cardiovascular diseases linked to sedentary lifestyles. The overarching goal should be to integrate regular, meaningful physical activity into daily life as a cornerstone of metabolic health, thereby reducing the burden of disease and improving quality of life across diverse populations.

**References**

Agbaje, A. O. (2023). Associations of Sedentary Time and Physical Activity from Childhood with Lipids: A 13-Year Mediation and Temporal Study. *The Journal of Clinical Endocrinology & Metabolism*, *108*(1), 122-132. https://dx.doi.org/10.1210/clinem/dgad688

Bailey, R. (2016). Potential Moderating Role of Upper Extremity Activity on Metabolic Effects of Sedentary Behavior in People with Stroke. *Physical Therapy*, *96*(1), 122-130. https://dx.doi.org/10.2522/ptj.2016.96.1.122

Bondge, B., Jain, J., Warkad, M., Joshi, M., More, S., & Janaarthanan, S. (2021). Association of Physical Activity with Lipid Profile in Healthy Subjects: A Cross Sectional Study in Tertiary Care Hospital from Central Rural India. *Indian Journal of Endocrinology and Metabolism*, *25*(6), 527-533. https://dx.doi.org/10.4103/ijem.ijem_327_21

Crichton, G., & Alkerwi, A. (2015). Physical

activity, sedentary behavior time and lipid levels in the Observation of Cardiovascular Risk Factors in Luxembourg study. *Lipids in Health and Disease*, *14*, 87. https://dx.doi.org/10.1186/s12944-015-0085-3

McGuire, K. A., Ross, R., & Earnest, C. (2011). Sedentary Behavior Is Not Associated with Cardiometabolic Risk in Adults with Abdominal Obesity. *PLOS ONE*, *6*(6), e20503. https://dx.doi.org/10.1371/journal.pone.0020503

Meneguci, C. A. G., Meneguci, J., Sasaki, J., Tribess, S., & Junior, J. S. V. (2021). Physical activity, sedentary behavior and functionality in older adults: A cross-sectional path analysis. *PLOS ONE*, *16*(1), e0246275. https://dx.doi.org/10.1371/journal.pone.0246275

Musić Milanović, S., et al. (2021). Socioeconomic disparities in physical activity, sedentary behavior and sleep patterns among 6- to 9-year-old children from 24 countries in the WHO European region. *Obesity Reviews*, *22*(S1), e13209. https://dx.doi.org/10.1111/obr.13209

Park, J., Moon, J., Kim, H., Kong, M., & Oh, Y. (2020). Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks. *Korean Journal of Family Medicine*, *41*(6), 372-380. https://dx.doi.org/10.4082/kjfm.20.0165

Peddie, M. C., Bone, J. L., Rehrer, N. J., Skeaff, C. M., Gray, A. R., & Perry, T. L. (2013). Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. *The American journal of clinical nutrition*, *98*(2), 358–366. https://doi.org/10.3945/ajcn.112.051763.

Strizich, G., Kaplan, R., Sotres-Alvarez, D., Diaz, K., Daigre, A., Carnethon, M., Vidot, D., Delamater, A., Perez, L., Perreira, K., Isasi, C., & Qi, Q. (2018). Objectively Measured Sedentary Behavior, Physical Activity, and Cardiometabolic Risk in Hispanic Youth: Hispanic Community Health Study/Study of Latino Youth. *The Journal of Clinical Endocrinology & Metabolism*, *103*(9), 3289-3299. https://dx.doi.org/10.1210/jc.2018-00356