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ORIGINAL ARTICLE

Sedentary Behaviour and Stroke: Foundational Knowledge is Crucial

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Abstract Physical activity is important for people's health. The emphasis over the last two decades has been on moderate to vigorous exercise when designing activity and exercise programmes for adults with stroke. Emerging evidence suggests that sedentary behaviour is distinctly different from a lack of moderate to vigorous physical activity and has independent and different physiological mechanisms. The concept of concurrently increasing moderate to vigorous physical activity and reducing sedentary behaviour may be beneficial for adults with stroke. This article discusses what we know about sedentary behaviour of adults with stroke and what research directions are needed to build foundational knowledge in this area with this population.

Keywords Stroke · Sedentary behaviour · Physical activity · Exercise · Health

In the general population, reduced physical activity is associated with a shorter life expectancy and a higher risk of developing type II diabetes, cardiovascular disease and some types of cancer [1, 2]. To reduce these risks, guidelines recommend at least 30 min of moderate-intensity physical activity on at least five days a week [2]. For decades, exercise professionals have promoted moderate- to vigorous- intensity levels of physical activity.

Stroke rehabilitation often focuses on improving or maintaining the aerobic fitness level, improving cerebrovascular health and brain perfusion. For the prevention of recurrent stroke and acute cardiac events in stroke survivors, modification of multiple risk factors is recognized as the cornerstone of initiatives. Physical activity can modify several predisposing vascular risk factors like high blood pressure, abnormal blood lipids, HDL cholesterol, obesity and diabetes mellitus [3]. So, it is no surprise that the American Heart Association recommends that stroke survivors should participate in structured physical activity programmes to improve health [4].

Although it is well-established that physical activity is important for one's health, recent evidence suggests that this is only part of the story. Sedentary behaviour and physical activity had previously been seen as two sides of the same coin. They are, however, different constructs in the activity continuum and have independent effects on health. Recent studies have consistently shown that a large amount of sedentary behaviour, as distinct from a lack of moderate to vigorous physical activity, is also associated with an increased risk of coronary heart disease, hypertension, diabetes, obesity, mortality and some cancers in the general population [5, 6]. Sedentary behaviour is characterized as any behaviour with extremely low-energy cost. Activity-related energy expenditure is quantified using metabolic equivalents of tasks (METs) [7]. The adverse health outcomes associated with sedentary behaviour (i.e. sitting/reclining) are independent of the total amount of moderate to vigorous physical activity performed [8]. It is increasingly clear that the amount of sedentary behaviour people engage in has a large impact on health, regardless of their level of physical activity [8]. It is therefore no surprise that the interest in decreasing sedentary behaviour

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(i.e. sitting/reclining) in the general population has exploded in the last decade, and this research area received widespread media attention with statements like 'too much sitting kills you' and 'sitting is the new smoking'.

Prolonged periods of sedentary behaviour in the general population have been associated with several metabolic risk factors and all-cause mortality, independent of participation in physical activity, suggesting that the health protective effects of physical activity may be negated by prolonged bouts of sedentary behaviour [6, 8]. So, some people who reach the levels of moderate to vigorous physical activity but at other times undertake significant periods of sedentary activity may be weakening the positive benefits of physical activity. Thus, public health programmes are now focusing on reducing or breaking up sedentary time in addition to increasing physical activity levels [9].

Based on these recent findings in the general population, it is time to rethink the physical activity guidelines for people with stroke. However, there is a lack of knowledge about sedentary behaviour in people with stroke. So, before future steps in clinical practice and research can be made, it is important to characterize the mechanisms explaining sedentary behaviour in adults with stroke.

Sedentary Behaviour

A common categorization of physical activity uses the terms sedentary, light, moderate and vigorous to describe specific intensity zones in a continuum from rest to high-intensity activity. Table 1 provides operational definitions and descriptive measures of these terms. The MET used in this table is a physiological measure expressing the energy cost of physical activities and is defined as the ratio of metabolic rate during a specific physical activity to a reference metabolic rate (1 MET). Sedentary behaviour is recently defined as any *waking* behaviour characterized by an *energy expenditure ≤1.5 METs* whilst in a *sitting* or *reclining posture* [10].

Table 1 Operational definitions of the activity continuum. MET = the metabolic equivalent of task (MET)

Activity level	Definition	Descriptive measure
Sedentary	≤1.5 METs	Activities that usually involve sitting or reclining and that have little additional movement
Light	1.6–2.9 METs	An activity that does not cause a noticeable change in breathing heart rate (eg. walking slowly, cooking a meal)
Moderate	3.0–5.9 METs	An activity that is able to be conducted whilst maintaining a conversation uninterrupted (walking at 3–4.5 mph, vacuuming, mowing lawn)
Vigorous	≥6.0 METs	An activity in which a conversation generally cannot be maintained uninterrupted (walking at ≥5.0 mph, jogging, cycling at ≥10 mph or uphill)

Sedentary behaviour may be a risk factor for health simply on the basis of low-energy expenditure. Importantly, previously, sedentary behaviour had been described as a muscular inactivity rather than the absence of light, moderate or vigorous physical activity [11]. The reduction or absence of muscle activity may place a person at a greater risk of developing metabolic diseases. Experimental data from cross-sectional studies in humans show that excessive sitting time, with contractile inactivity in postural muscles, is associated with adverse changes in circulating lipids and insulin sensitivity and causes a disruption of triglyceride and high-density lipoprotein cholesterol metabolism. Consistently, observations in free-living humans by objective monitoring of body movement suggest that regular interruptions in sedentary time are associated with lower triglyceride levels. Brief interruptions of sitting lead to significant reductions in postprandial glucose and insulin, irrespective of the activity intensity. Thus, even brief interruptions of sitting time may potentially be an important public health and clinical intervention [12, 13].

The recently published definition of sedentary behaviour includes two components: (1) posture (sitting or reclining) and (2) energy expenditure (<1.5 METs). It is surprising that, given the theoretical assumption that a lack of muscle activity contributes to the negative health outcomes associated with sedentary behaviour, muscle (in)activity is not part of the currently accepted definition. This 'problem' has been solved by describing postures in which most of the body's largest muscles are under relaxation (i.e. sitting or reclining) in the definition. Static standing is not considered sedentary behaviour because a large proportion of the body's muscles are active during standing [6], which is assumed to be reflective of higher energy demands. Thus, due to the lack of demand for recruitment of larger muscle groups, activities that require 1.0–1.5 METs are considered to be sedentary behaviours. Therefore, posture, energy expenditure and muscle activity are the three important factors that are related to sedentary behaviour.

Sedentary Behaviour in People with Stroke?

We do not know if the currently accepted and published definition of sedentary behaviour [10], and foundational research about muscle (in)activity in the general population, is applicable to people with stroke. The neuromuscular deficits present, e.g. atypical muscle tone, impaired coordination, muscle co-contraction, balance and sensory deficits, are likely to influence muscle activity and energy expenditure in different postures. Given the range of impairments in people with

stroke, the patterns of energy expenditure and muscle activity may differ across different levels of motor involvement. For the general population, there are few exceptions in which an individual can be sitting or lying down but still have a high enough level of energy expenditure (e.g. riding a bike) to be considered non-sedentary. However, it is possible that the muscular and energy demands required for some adults with stroke to maintain their balance and stabilizing their trunk whilst sitting are high enough to define sitting as non-sedentary. In the general population, standing would not normally be considered as sedentary behaviour since there are generally some nondescript small movements, such as shifting or fidgeting during standing. However, for patients with stroke who use a walking aid during standing positions, we do not know how many and what muscle groups are active whilst standing. Some patients might use their walking aid and the muscles in their upper extremities and trunk to maintain their posture. This could result in less muscular activity from the big muscle groups and consequently less energy expenditure. So, we cannot necessarily take the definition for healthy adults and apply it to people with stroke since we do not know if adults with stroke are really sedentary whilst sitting, and whether they are non-sedentary whilst standing. This shift in thinking creates measurement challenges, since sedentary behaviour in people with stroke has been traditionally measured in a number of ways, both subjectively and objectively. Subjectively, sedentary behaviour has most frequently been measured by self-report using activity questionnaires [14]. Objectively, accelerometers have become the standard method of measurement to collect information regarding the intensity of movement [15]. However, both methods might not be valid proxy indicators of sedentary behaviour because first, accelerometers do not inform on body posture; thus, they cannot distinguish between sitting and standing still [15], and second, we do not know if people with stroke are really sedentary whilst sitting and non-sedentary whilst standing in terms of energy expenditure and muscle activity.

Research Priorities and Future Directions

The concept of reducing sedentary behaviour opens the possibility of innovative intervention options for people with stroke. Based on current evidence, we do not know the optimal time windows for neuroanatomical effects of rehabilitation and for behavioural effects of rehabilitation [16, 17]. Moreover, at this point, we cannot design or implement an appropriate intervention to influence the health of people with stroke using the whole physical activity continuum. A clear understanding of how to define sedentary behaviour with this population is essential. An evaluation of energy consumption and muscle activity during a range of postures that approximate sedentary behaviour (i.e. sitting and standing) among individuals with stroke would provide important information about the actual physiologic demand and would begin to unravel the factors related to sedentary behaviour. The severity of motor deficits between patients is extremely variable among adults with stroke, and it is likely that there is heterogeneity in their energy expenditure and muscle activity in different postures. The physiological mechanisms, muscle activity and energy expenditure levels that represent sedentary behaviour in patients with stroke may be very different from the regular population and need to be examined. So, before we can start exploring the effect of sedentary behaviour on health outcomes in adults with stroke, it is essential that the potential mechanisms (muscle contractions and energy expenditure) underpinning the association between sedentary behaviour and health are better characterized.

This could be done by studying muscle activity and energy expenditure in different postures in people with stroke with a range of severities. For example, an evaluation of energy consumption during different movement activities among adults with different severity of motor impairment would provide important information about the actual energy expenditure in different postures. Electromyographic recordings could be used simultaneously to assess muscle activity in different positions. Combining the energy expenditure and EMG information with descriptive information about supports and walking aids would provide an understanding of the interaction between posture, energy expenditure and muscle activity in people with stroke.

Conclusion

For decades, exercise professionals have been emphasizing the need for structured moderate to vigorous exercise as the guiding tenant of physical activity and exercise programme design for adults with stroke. The concept of concurrently increasing moderate to vigorous physical activity and reducing sedentary behaviour may be beneficial for adults with stroke.

Before intervention recommendations for this population can be broadened, it is important to try to unravel the mechanisms explaining sedentary behaviour. We therefore need to build foundational knowledge about definitions and classifications specific to individuals with stroke.

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