



Isotemporal Substitution Model: Analysis of Physical Activity to Prevent a Sedentary Lifestyle

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Abstract

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The phenomenon of a sedentary lifestyle is increasing, coinciding with the growing dominance of technology-based activities in academic environments. At Makassar State University, lecturers and educational staff spend most of their working time sitting, increasing the risk of health problems. This study aims to design a physical activity model based on the Isotemporal Substitution Model (ISM) as a preventive measure against sedentary behaviour. The method used is Design Science Research Method (DSRM), which includes stages of problem identification, requirements formulation, artefact design, demonstration, and evaluation. The results indicate that the developed artefact—a model for substituting sitting time with various categories of physical activity (moderate, vigorous, very vigorous aerobic activity, and muscle strengthening)—can be adaptively applied by lecturers and educational staff according to work conditions and available time. The implementation of this model is recommended to be supported by institutional policies and institutional health programs to ensure sustainability and provide a long-term, positive impact on the quality of life of the academic community.

Keywords: Isotemporal Substitution Model, physical activity, sedentary behaviour, DSRM, UNM

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INTRODUCTION

The modern lifestyle, increasingly dependent on technology, has significantly altered human activity patterns. Around the world, the majority of adults spend most of their time in a seated or physically inactive state (Tremblay et al., 2017). Activities dominated by sitting in front of computers, watching television, or driving long distances have become daily routines that are difficult to avoid. This phenomenon is known as sedentary behaviour, defined as activities with very low energy expenditure, typically below 1.5 METs (Metabolic Equivalent of Task). Studies indicate that the global prevalence of sedentary behaviour has risen in line with the shift towards more sedentary occupations (Mansoubi et al., 2015).

Similar conditions also occur in Indonesia. According to data from various national health surveys, the average adult in Indonesia spends about 8 hours per day sitting or engaging in low-intensity activities (Dika & Shpuza, 2024). This lifestyle is often related to job demands that require long hours in front of a screen, whether for administrative work, academics, or other digital activities. Extended periods of sitting without light physical activity have been shown to increase the risk of various health disordersn (J. H. Park, Moon, Kim, Kong, & Oh, 2020).

Globally, sedentary behaviour has been identified as one of the significant risk factors for the emergence of non-communicable diseases (NCDs) such as coronary heart disease, type 2 diabetes mellitus, and obesity (Cao, Xu, Zhang, & Wang, 2022). For example, global reports indicate that around 27.5% of adults in 2016 did not meet the recommended physical activity guidelines, and sedentary trends play a role in the increasing burden of NCDs. Additionally, systematic research has shown that prolonged sitting time is linked to worsening obesity indicators (Wu et al., 2023).

An imbalanced diet and chronic stress conditions also contribute to the rising prevalence of non-communicable diseases. Consuming foods high in saturated fats, sugar, and salt without adequate fibre intake exacerbates the body's metabolic condition (Katzmarzyk, Friedenreich, Shiroma, & Lee, 2022). Meanwhile, prolonged stress can disrupt hormonal balance and increase unhealthy behaviours such as overeating or avoiding physical activity. The combination of these factors creates a reinforcing cycle of health problems. Research indicates that allocating time for physical activity, following a structured diet, and managing stress simultaneously is crucial in the prevention of NCDs (Zhang, Ngai, Yang, & Xie, 2025).

In the context of non-communicable disease prevention, physical activity plays a significant role. Regular physical activity performed at the appropriate intensity can enhance cardiorespiratory fitness, improve insulin sensitivity, and reduce blood pressure and body fat levels (Saqib et al., 2020). Numerous studies have demonstrated that increasing the duration and intensity of physical activity can significantly reduce the risk of death from NCDs. Therefore, interventions that encourage the public to be more active should be a priority in health promotion and preventive efforts (Murlasits, Kupai, & Kneffel, 2022).

The academic environment, particularly within higher education institutions, is one of the groups vulnerable to sedentary behaviour. Students and lecturers often spend hours engaged in lectures, reading, writing, and working on computers. Physical activity tends to be limited, while academic pressure and busy schedules reduce the time available for exercise. This situation makes the campus environment a strategic place to implement physical activity-based intervention programmes (Sutherland, Cole, Kynn, & Gray, 2024).

The Isotemporal Substitution Model is an analytical approach used to understand the health impact of replacing one type of activity with another over the same period. Simply put, this model emphasises the importance of time as a fixed resource, so that an increase in physical activity duration can only occur by reducing the time spent on other activities such as sitting or sleeping. This model has been utilized in epidemiological studies to evaluate how the redistribution of time among various types of activities (e.g., sitting, light activity, moderate-to-vigorous activity) impacts overall health (Mekary & Ding, 2019).

The application of the Isotemporal Substitution Model is important as it offers a more realistic approach in the context of everyday life. Rather than merely increasing exercise duration, this model emphasises a more practical and measurable strategy of time replacement. For instance, replacing 30 minutes of sitting time with light walking can have a significant impact on reducing cardiovascular risk (Biddle et al., 2021). Recent studies suggest that substituting

sitting time with light or moderate-to-vigorous physical activity is associated with decreases in body fat and waist circumference. Consequently, this model can provide evidence-based recommendations relevant to planning public health interventions (Dumuid et al., 2019).

Several previous studies have demonstrated that the application of isotemporal substitution is practical in enhancing health parameters, including physical fitness, body composition, and metabolic indicators. For example, a study using an isotemporal model found that substituting sitting time with walking or moderate-to-vigorous activities was associated with reductions in waist circumference and body fat percentage (Galmes-Panades et al., 2019). The use of this model also helps researchers understand the dynamics of the balance between activity, rest, and sleep time. In the academic environment, this model has the potential to serve as a basis for designing physical activity programs suited to the lifestyles of students and busy educational staff (de Victo et al., 2025).

Within the framework of preventing sedentary behaviour in academic settings, understanding the Isotemporal Substitution Model becomes highly relevant (Gu et al., 2024). Through this approach, interventions can be designed taking into account the specific characteristics of students, such as class schedules, study patterns, and levels of academic stress. Thus, the resulting strategies are not only theoretical but also applicable and sustainable within campus life.

This study aims to design physical activity patterns based on the Isotemporal Substitution Model as an effort to prevent sedentary behaviour in academic environments. Through this approach, it is expected to develop an activity model that balances academic needs and physical health. The results of this research are expected to serve as a foundation for the development of health promotion policies in higher education institutions, contributing to an enhanced overall quality of life for the academic community.

METHODS

This study adopts the Design Science Research Method (DSRM) approach as the main framework for developing and evaluating the Isotemporal Substitution Model (ISM) in the context of public health behaviour analysis. DSRM, first proposed by Hevner et al. (2004) and further developed by Peffers et al. (2007), is a methodology oriented towards creating solution artifacts to solve practical problems through an iterative cycle of design, implementation, and evaluation. This approach was chosen due to its holistic nature, which enables the integration of theoretical knowledge and empirical application, making it suitable for our research aims of designing a time substitution model applicable to longitudinal data on physical activity and sleep.

The DSRM process in this research is structured into six main stages, as outlined by Peffers et al. (2007), with contextual adjustments for the ISM topic. First, the **Explicate Problem** involves identifying challenges in time substitution modelling where the allocation of duration for specific activities (such as exercise, sitting, or sleeping) impacts health outcomes isotemporally, with total daily time remaining constant. This issue is based on a literature review showing the limitations of conventional models in handling the compositional variability of time data, as discussed in previous epidemiological studies. (Mekary & Ding, 2019).

Secondly, the **Define Requirement** aims to design an artefact in the form of a flexible ISM model, capable of simulating the adjustment of time between activities while maintaining compositional principles. This solution is designed to provide a more accurate estimation of marginal effects on health indicators, such as cardiovascular risk, by accounting for the interaction between temporal variables.

Thirdly, the **design and development** of the artefact is carried out through a physical activity approach that is appropriate based on physical activity categories and types of physical activities that can be performed within the scope of Makassar State University. The Physical Activity Model can be undertaken by lecturers, educational staff, and even students, by adapting to other activities and the needs of each individual.

Fourth, **demonstration of the artefact** through testing the ISM Model in simulation studies on samples, where the substitution of sleep time with physical activity is being explored. This demonstration illustrates the model's capacity to generate predictions consistent with previous empirical findings, such as improvements in metabolic health resulting from replacing sedentary time with walking.

Fifth, an **Evaluation** was conducted iteratively using performance metrics, such as root mean square error (RMSE) and coefficient of determination (R^2), in comparison with traditional substitution models. In addition, external validation involved health domain experts assessing the artefact's usefulness, with feedback collected through semi-structured interviews.

Thus, the application of DSRM in this research bridges the gap between the theory of time substitution and practical implementation, while maintaining the methodological rigor required in scientific studies.

RESULTS & DISCUSSION

Results

The research results, based on the Design Science Research method, on the Isotemporal Substitutional Model at Makassar State University, followed several analysis models with stages that started from Explicate Problem, Define Requirements, Design and Develop Artefact, Demonstrate Artefact, and Evaluate Artefact.

Explicate Problem

The Isotemporal Substitution Model is based on the assumption that time spent on one type of activity is limited — increasing time for one activity always comes at the expense of time for other activities. In this context, the primary issue identified is the high proportion of sitting time and low physical activity in workplace and institutional settings. Based on the fishbone diagram, this problem can be broken down into five main causal dimensions: Man, Machine, Method, Material, and Environment.

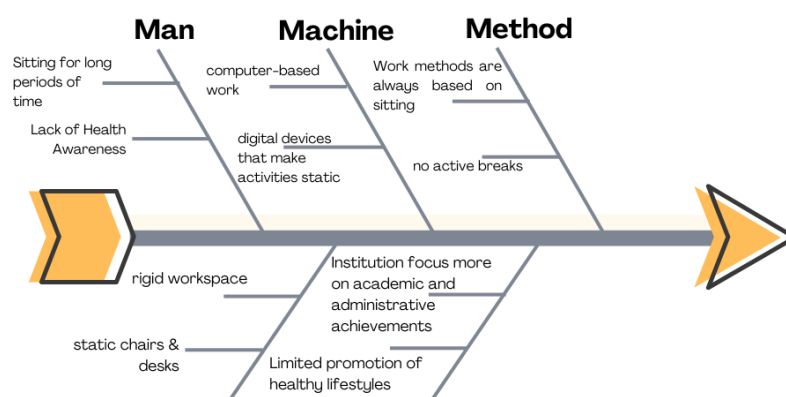


Figure 1. Fishbone for Isotemporal Substitution Model

Human factors play a significant role in shaping sedentary behaviour. A lack of awareness about the importance of physical activity and the habit of sitting for prolonged periods is the primary root of the issue. Many individuals perceive sitting as a neutral and comfortable position without recognising the long-term health impacts, such as metabolic and postural disturbances. Within the framework of Isotemporal Substitution, changing this behavior requires a redistribution of time, where some sitting time is replaced with light or moderate-intensity activities to optimize health benefits without altering the total work duration.

In addition to individual factors, the use of technology or machines also reinforces a sedentary lifestyle. Computer-based work and dependence on digital devices lead to increasingly sedentary activity. Technology, which is supposed to support work efficiency, often limits movement and prolongs sitting duration without conscious awareness. It is exacerbated by work methods that do not encourage active breaks or interruptions to physical activity during working hours. Thus, both technology design and monotonous work systems directly contribute to the failure to implement the principle of more active time substitution.

Environmental and material factors also reinforce these barriers. A rigid work environment, the use of static chairs and desks, and an institutional focus on academic and administrative productivity without promoting a healthy lifestyle create a passive work culture. This situation illustrates a structural imbalance where physical health becomes a secondary priority. Based on the Isotemporal Substitution model, these conditions indicate a failure to allocate time optimally between sedentary and physical activities. Therefore, effective interventions should not only change individual behaviour but also reorganise work systems and environmental design to enable the sustainable substitution of sitting time with more dynamic activities.

Define Requirement

Root Cause Analyses are conducted to identify the fundamental factors contributing to the context of the Isotemporal Substitutional Model in the environment of Makassar State University. Root Cause Analyses are carried out through the design of “Why-Why Solution” questions as shown in Table 1.

Table 1. Root Cause Analysis for Isotemporal Substitutional Model at Universitas Negeri Makassar

Why	Detail	Solution
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Why 1	Why do lecturers and teaching staff spend more time sitting during their daily activities	Their work is predominantly computer-based (online teaching, preparing materials, academic administration, student service)
Why 2	Why is physical activity rarely done during breaks at work?	The academic and administrative workload is heavy, leaving very little time for physical activity
Why 3	Why is sitting time not substituted with other activities (walking, stretching, short exercise)?	There are no policies or campus culture that encourage replacing sedentary activities with light physical activities.
Why 4	Why is awareness among lecturers/teaching staff about the benefits of isotemporal substitution low?	The institution does not provide much education or training on health lifestyle based on activity time management.
Why 5	Why are lifestyle-based health programs not yet a priority on campus?	The institution's focus is more on academic performance, administration, and formal achievements, while the health of human resources is not yet seen as a strategic factor sustainability.

Based on the results of the Isotemporal Substitutional Model analysis at the university, several aspects that are the focus of the root problems consist of: (1) A very static work pattern (sitting for long periods in front of a computer); (2) Limited time, opportunities, and facilities for physical activity; (3) Lack of education and institutional programs that encourage substitution of activities; and (4) Institution policy focus on work productivity rather than lifestyle balance. The identified root problems were then categorised to design and create solutions to address the issues found in the Define Requirement as per the following Table 2:

Table 2. Define Requirement for Isotemporal Substitutional Model at Universitas Negeri Makassar

Category	Define Requirement
Education	Health Education (seminars/workshops) for lecturers and teaching staff on the benefits of activity substitution.
Technology	Encourage walking meetings or short standing meetings.
Regulation	Create a healthy campus program; for example, walking challenges, group stretching exercises or light exercise facilities near the office.
Mentoring	Provide 5-10 minutes of active rest every 1-2 hours of sitting.

Design and Develop Artefact

The development of an artefact model within the framework of the Isotemporal Substitution Model is designed to facilitate the structured and measured transformation of sedentary behaviour into more active patterns. This artefact design is based on four categories of physical activity, namely: (1) moderate aerobic activity, (2) vigorous activity, (3) very vigorous activity, and (4) muscle strengthening. Each category has different goals and intensities, yet they complement each other in forming balanced activity patterns for lecturers and teaching staff. Through this approach, the artefact serves as a practical guide that helps individuals understand how time typically spent sitting can be redirected to various forms of physical activity without disrupting their daily work duration and rhythm.

Based on these four categories, model users — in this case, lecturers and educational staff — will be guided to select and determine the type of activity most suitable for their physical condition, time availability, and job characteristics. These activities are classified according to their frequency of execution, namely daily activities, three times a week, and once a week. This division enables the realistic application of isotemporal substitution, whereby some sitting time is gradually and consistently replaced with other activities. This adaptive approach emphasises not only the quantity of activity but also the quality of time substitution so that health benefits can be achieved without reducing work productivity.

Table 3. Types of Physical Activity Based on the Physical Activity Categories of Lecturers and Administrative Staff at Universitas Negeri Makassar

Physical Categories	Activity	Types of Physical Activities (Lecturers & Staff)
Moderate Aerobic Activity		Walking between lecture buildings (for example, from the Pinisi Building to the Faculty), using the campus stairs instead of the lift, taking a leisurely walk around the campus before or after teaching, doing light stretches in the staff room every hour while seated, or cycling leisurely to campus.
Vigorous Activity		Jogging on the UNM Gunungsari or Banta-Bantaeng campus grounds, engaging in morning exercise together in the faculty environment, participating in routine sports activities such as campus fun runs, or playing badminton with colleagues in the UNM sports facilities.
Very Vigorous Activity		Engaging in high-intensity interval training (HIIT) at the UNM fitness centre, participating in inter-faculty sports competitions such as futsal or basketball, high-intensity weight training, or medium-distance cycling around Makassar over the weekend.
Muscle Strengthening		Performing simple strength exercises in the workplace (such as squats, lunges, or planks),

attending yoga or bodyweight exercise classes at the campus sports unit, using resistance bands during breaks, or performing stretching exercises focused on the back and shoulders to reduce the effects of prolonged sitting.

In addition, this artefact is designed with a participatory principle, where the selection and implementation of activities are carried out through consultation with technical implementing units focused on physical activities or health promotion. The involvement of these units ensures that the recommended activities comply with health guidelines, are safe to conduct, and can be integrated into institutional work routines. With technical guidance, the application of the Isotemporal Substitution Model is expected not only to be individual but also to become part of the institutional support system in fostering an active and healthy work culture.

Demonstrate Artefact

Demonstration of the Isotemporal Substitution Model artefacts within UNM can be conducted through the direct application of physical activities integrated with the work routines of lecturers and educational staff. Implementation begins with socialization and the selection of physical activities based on four main categories: moderate, strenuous, very strenuous aerobic activities, and muscle strengthening. Each lecturer is guided to adjust the chosen activity to match their workload and academic schedule, for example, by walking between lecture buildings, climbing campus stairs, or doing light stretching during breaks between teaching and administrative duties. Meanwhile, high-intensity activities such as group aerobics, futsal, or HIIT training can be scheduled periodically, such as three times a week or every weekend, in campus sports facilities. This approach demonstrates that reallocating some sitting time to physical activity is not only feasible but can also be naturally integrated into daily academic activities without disrupting productivity.

Furthermore, this artefact can be institutionally demonstrated through collaboration between lecturers, educational staff, and technical implementation units (UPTs) focused on physical activities, such as the Sports and Health UPT. Through consultation and technical guidance, participants will receive recommendations for activities that suit their physical condition and work patterns. The implementation of activities can be supported by digital reminder systems or visual guides installed in lecturer rooms and public campus areas to encourage the consistent application of sitting time substitution. Thus, the demonstration of this artefact not only serves as a test of the Isotemporal Substitution concept but also marks an initial step in fostering an active work culture at UNM, which positions health and the balance of physical activity as integral to the sustainability of academic human resources.

Evaluate Artefact

The evaluation of the Isotemporal Substitution Model artifact at UNM is conducted to assess the effectiveness of the model's implementation in reducing sedentary time and increasing physical activity among lecturers and educational staff. The evaluation process can be carried out through quantitative and qualitative

approaches, such as measuring changes in sitting duration, increases in the frequency of physical activity, and participants' perceptions of the ease of integrating the artefact into their work routines. Survey and observation instruments are used to assess the extent to which physical activities, ranging from moderate aerobic to muscle-strengthening exercises, are successfully integrated into daily, tri-weekly, or weekly schedules. Additionally, the evaluation includes an analysis of participants' motivation and adherence levels to the provided guidelines, which serve as important indicators of the success of the artefact's implementation as a behavioural change instrument in an academic setting.

From an institutional perspective, the evaluation is conducted by the Technical Implementing Unit (UPT), which focuses on physical and health activities to assess the sustainability of the programme, as well as campus policy support for the implementation of the Isotemporal Substitution Model. The evaluation results are expected to provide an overview of the extent to which this artefact contributes to increased health awareness, work time efficiency, and the strengthening of an active work culture at UNM. The evaluative findings can be used as a basis for improving the artefact's design, both in technical aspects, such as developing a more adaptive activity schedule, and strategic aspects, such as integrating the programme into the welfare policies for lecturers and staff. Thus, the evaluation process not only serves to assess short-term success but also to ensure that the artefact has a long-term impact on the development of healthy, productive, and sustainable human resources within the UNM.

Discussion

The implementation of ISM artefacts in the UNM environment presents strategic opportunities to replace a portion of the sedentary time of lecturers and educational staff with light to vigorous physical activity, as categorized by established guidelines. Findings from previous research indicate that replacing sedentary time with moderate or vigorous physical activity is significantly associated with a reduction in the risk of various adverse health outcomes — for example, systematic studies conclude that shifting sedentary time to light or moderate-to-vigorous activity may be associated with reductions in body mass index, body fat, and waist circumference (Cao et al., 2022). In the context of UNM, this artefact can serve as an important instrument in actualizing that evidence within an academic system characterized by computer-based work, administration, and teaching that essentially involves seated positions.

Furthermore, when lecturers or educational staff choose moderate or vigorous aerobic activities, such as brisk walking between campus buildings, morning exercises together, or muscle-strengthening exercises during teaching breaks, the ISM artefact allows for substituting sitting time with physical activity without increasing the total working hours. The basic principle of ISM is that time is a limited resource — increasing time spent on one activity means reducing time on another. Thus, this artefact helps individuals realise that replacing part of their sitting time with physical activity is realistic within the campus work context. Previous research has shown that replacing sitting time with moderate or vigorous activity is associated with better sleep quality (Mekary & Ding, 2019). Thus, the artefacts at UNM are not only focused on 'increasing' physical activity, but on 'replacing' some of the static time with active time.

The successful implementation of ISM artefacts at UNM is highly dependent on institutional and campus cultural factors. Factors such as low awareness of the benefits of reallocating activity time, the lack of institutional policies that encourage physical activity, and the dominance of work schedules demanding intensive computer use — all of these constitute obstacles. It aligns with findings that many ISM studies indicate that substituting sedentary time with physical activity has the most significant impact when there is environmental support and policies that facilitate behavioural change (Dumuid et al., 2019). Therefore, UNM artefacts must be accompanied by institutional strategies and awareness campaigns to strengthen their adoption.

In evaluating artifacts, it is essential to consider the intensity and frequency of activities chosen by faculty/staff at UNM. Based on evidence, replacing sitting time with higher-intensity physical activity (moderate to vigorous) shows more potent effects on health outcomes compared to light-intensity activity. For example, studies in Latin America have shown that replacing 30 minutes per day of sitting time with moderate to vigorous activity is associated with lower odds of having a high body mass index or a large waist circumference (Moura, Rufino, Faria, & Amorim, 2019). Therefore, UNM artefacts that include categories of vigorous and very vigorous activity, as well as muscle strengthening, are highly relevant to optimise in order to maximise health impact.

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Theoretically, the implementation of ISM artefacts at UNM allows for the enhancement of the welfare of lecturers and educational staff by promoting a balance between academic duties and physical health. It has significant implications for the development of productive and sustainable human resources in the higher education environment. Outcome-wide analysis studies show that sitting for more than 6 hours a day is associated with a higher risk of 12 out of 45 non-communicable diseases (NCDs) when controlled through a time substitution model (Torres-Carballo et al., 2025). Consequently, artefacts that successfully reduce sitting time systematically could become part of a comprehensive campus health strategy.

Ultimately, although empirical evidence strongly indicates the benefits of substituting physical activity for health, there are still research limitations that must be considered in evaluating UNM artefacts. Most ISM studies are cross-sectional, making it difficult to definitively establish causality (J. Park, Nam, & Cho, 2024). Therefore, UNM needs to conduct long-term (longitudinal) evaluations and use objective measurements (such as accelerometers) to ensure the impact of artefacts on the health of lecturers/educational staff. Moreover, local cultural adaptation, academic variables, and the balance between teaching duties

and physical activity must be thoroughly examined so that such artefacts can be sustainably integrated within the campus context. This way, the artefacts will not only serve as temporary interventions but as part of a work culture change that promotes active and productive health at UNM.

CONCLUSION

The workload of lecturers and teaching staff requires them to spend a lot of time sitting down. Appropriate physical activity is important to prevent sedentary behavior in the academic environment. This artifact was designed using the DSR method, which involves identifying problems through several stages and then designing artifacts that are suitable for the academic environment at UNM. This artifact will be developed with the involvement of experts from the Faculty of Sports Science and Health and then implemented as a guideline within the UNM environment.

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