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Article

The impact of biomechanical factors on tourist satisfaction and comfort in walking tourism: A study of Beijing's walking tours

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Abstract: Walking tourism combines physical activity with cultural and environmental exploration, making it a growing sector of the tourism industry. This study investigates the effects of key biomechanical factors—fatigue and energy expenditure—on tourist experiences, specifically focusing on satisfaction and comfort during walking tours in Beijing. Using a structured questionnaire administered to 175 participants across various walking tour sites—including the Great Wall, Hutongs, and the Summer Palace—we collected data on perceived fatigue, energy expenditure, satisfaction, and comfort. Statistical analyses, including regression models and correlation tests conducted using SPSS, revealed that increased fatigue significantly reduces tourist satisfaction, while higher energy expenditure decreases comfort levels. These findings highlight the importance of managing physical demands in walking tours by incorporating rest periods and considering tourists' fitness levels. The study contributes to the literature by linking biomechanical factors to tourist experiences and offers practical recommendations for tour operators to enhance the appeal and competitiveness of walking tours, ultimately leading to improved tourist satisfaction.

Keywords: fatigue; energy expenditure; tourist satisfaction; comfort; walking tourism; Beijing

1. Introduction

Walking tourism has emerged as a highly popular form of travel, offering tourists an immersive way to engage with both natural and urban environments, and contributing positively to their health and well-being [1]. This type of tourism combines physical activity with cultural and historical exploration, making it an attractive option for those seeking both adventure and education. While the psychological and service quality aspects of tourism have been widely studied, the biomechanical aspects of walking tourism—such as fatigue and energy expenditure—remain underexplored. These biomechanical factors, crucial for understanding the physical demands placed on tourists, significantly impact their overall satisfaction and comfort during walking tours, and are essential considerations for sustainable destination development [2].

Despite the growing popularity of walking tourism, existing research primarily focuses on service quality, satisfaction, and the psychological experiences of tourists, with some studies exploring its role in rural development [3]. Limited attention has been paid to the physiological influences that shape tourist experiences, particularly in the context of extended walking activities. The physical exertion required in walking tourism can lead to fatigue and high energy expenditure, which may diminish a tourist's enjoyment, regardless of the cultural or scenic value of the tour. This gap in the literature presents an opportunity to investigate how these biomechanical factors specifically affect tourist satisfaction and comfort during walking tours. The model focuses on the relationship between the biomechanical factors—fatigue and energy expenditure—and tourist experience metrics like satisfaction and comfort. Both fatigue and energy expenditure were calculated using a similar formula, based on participant responses.

Beijing, with its blend of historical landmarks, cultural sites, and urban landscapes, offers an ideal setting for studying the effects of biomechanical factors on walking tourism experiences. The city encompasses a diverse range of walking environments, from the steep inclines and uneven steps of the Great Wall, which challenge physical endurance, to the flat, narrow alleyways of the Hutongs, rich in cultural heritage but requiring minimal physical exertion [1,2]. Additionally, sites like the expansive grounds of the Summer Palace combine natural landscapes with historical architecture, offering moderate physical activity amid scenic beauty [3].

These varied environments present different built and natural characteristics that influence tourist experiences. The Great Wall's rugged terrain and altitude changes demand higher energy expenditure and may lead to increased fatigue, affecting satisfaction and comfort [4]. In contrast, the Hutongs offer shaded, level pathways that facilitate leisurely exploration, potentially enhancing comfort and overall enjoyment [5]. The Summer Palace's mix of gentle slopes, water features, and open spaces provides a balance of physical activity and relaxation, appealing to a wide range of tourists [6].

This diversity makes Beijing a relevant location for analyzing how fatigue and energy expenditure influence the overall tourist experience, as well as how these factors interact with different types of walking tours.

The objective of this study is to investigate the relationship between two key biomechanical factors—fatigue and energy expenditure—and tourist satisfaction and comfort in walking tourism. Specifically, the research aims to quantify how increased physical strain affects a tourist's perception of enjoyment and comfort during walking tours in Beijing. Reliability was tested using Cronbach's alpha, and validity was confirmed through factor analysis. By addressing this gap, the study provides insights into how physical exertion influences the tourist experience, offering practical recommendations for optimizing tour design and management.

Through using structured questionnaires and statistical analysis with SPSS, we quantified the effects of fatigue and energy expenditure on tourist experiences. The findings have practical implications for tour operators and destination managers, providing actionable recommendations for designing walking tours that enhance tourist satisfaction and comfort. These results can also contribute to the growing field of tourism management by offering a biomechanical perspective that complements the traditional focus on psychological and service-related factors.

2. Theoretical basis and literature review

2.1. Fundamental biomechanical concepts in walking tourism

2.1.1. Basic concepts of biomechanics

Biomechanics, in the context of walking tourism, plays a fundamental role in understanding human movement, focusing on three primary aspects: gait analysis, kinematics, and dynamics. These concepts allow for a comprehensive understanding of how the human body interacts with the environment during walking, which is critical for optimizing tourist experiences and ensuring safety on various terrains.

Gait analysis examines the sequence of movements involved in walking, focusing on how different phases of the gait cycle (heel strike, mid-stance, and toe-off) affect overall movement efficiency. Studies have shown that variations in walking speed and terrain directly influence gait mechanics, particularly in terms of knee and ankle flexor moments, which are crucial for maintaining a natural gait during extended walking activities like tourism [1]. Additionally, gait analysis is important for understanding how to maintain balance and stability. Parameters like the Center of Pressure (CoP) and the Zero-Moment Point (ZMP) are commonly used to assess an individual's stability during walking, especially on uneven or sloped surfaces, which are common in walking tourism [2].

Kinematics refers to the description of motion without considering the forces that cause it. In walking tourism, kinematic analysis involves studying joint angles, step lengths, and stride frequency. For example, the biomechanics of human walking vary significantly with speed, and these changes can have implications for both the comfort and safety of tourists. A kinematic study on different walking speeds revealed that adjustments in step length and gait patterns can reduce stress on joints, particularly the knees, by distributing the load more evenly across the body [3]. This information is valuable in designing walking tours that minimize fatigue and discomfort, especially for long distances.

Dynamics, on the other hand, focuses on the forces that generate motion, including the interaction between the body and the ground during walking. Research has highlighted the importance of understanding the forces exerted by the feet on the walking surface, as well as the reaction forces that the surface provides. Dynamic models of walking are useful for predicting how tourists might react to different walking conditions, such as uphill or downhill terrains, and how these conditions affect energy expenditure and muscle activation [4]. Furthermore, dynamic stability is critical for preventing falls, especially when walking on irregular or challenging surfaces. To enhance stability and reduce physical demands, assistive devices such as walking aids have been utilized, particularly benefiting elderly or mobility-impaired tourists [5]. This support is crucial in preventing falls and ensuring safety during walking tourism activities.

Overall, understanding these basic biomechanical concepts—gait analysis, kinematics, and dynamics—provides valuable insights for improving the design and safety of walking tourism routes. This allows for the development of more enjoyable and less physically demanding experiences for tourists, while also ensuring that biomechanical principles are applied to reduce injury risks and improve overall walking efficiency.

2.1.2. Impact of biomechanical factors on the human body (expanded)

Balance and stability are critical for ensuring safety during walking tourism, especially when navigating uneven or challenging terrains. The ability to maintain stability while walking involves a complex interplay between sensory input and motor control. Key biomechanical parameters, such as the Center of Pressure (CoP) and Zero-Moment Point (ZMP), are used to assess an individual's balance during walking. Studies have shown that walking on varied surfaces, such as sloped or irregular terrain, requires the body to make constant adjustments to maintain stability, which places additional demands on muscles and joints [6]. Research has further demonstrated that assistive devices, such as robotic exoskeletons or walking poles, can enhance stability by providing additional support, helping individuals maintain balance even in difficult conditions [5]. This is especially important for elderly or mobility-impaired tourists, for whom balance control is crucial in preventing falls.

Joint load refers to the mechanical forces exerted on the joints, particularly the knees and ankles, during walking. In walking tourism, managing joint load is crucial to avoid injuries, as prolonged walking on varied terrains can increase stress on the joints. Biomechanical studies indicate that walking on uneven surfaces or at faster speeds places additional load on the joints, which can lead to discomfort and fatigue [7]. However, interventions like body-weight unloading systems have been shown to reduce joint strain while maintaining natural gait mechanics [4].

Muscle activity is another vital factor in walking tourism, as it determines the amount of physical effort required to maintain movement and balance. Walking on uneven or challenging terrain increases muscle activation in the lower limbs, particularly in the quadriceps and calf muscles, which are responsible for stabilizing the body and propelling it forward. Studies show that muscle fatigue can occur more quickly on complex walking paths, leading to a decrease in performance and enjoyment [8]. To mitigate this, tourism planners can design walking routes that include varied terrains, along with opportunities for rest and the use of supportive equipment, which can help reduce muscle fatigue and improve endurance [9].

Energy consumption during walking is directly related to the biomechanics of movement. Walking on uneven or inclined terrain increases energy expenditure as the body works harder to maintain balance and overcome gravitational forces. Biomechanical research indicates that optimizing gait patterns—such as adjusting joint angles, step lengths, and stride frequency—can help reduce energy consumption and improve walking efficiency [10]. Moreover, the use of powered exoskeletons or assistive devices has been found to significantly reduce metabolic costs, making walking easier and more sustainable, especially for elderly or physically challenged individuals [6].

Gait analysis examines how people walk and identifies patterns in their movements. By understanding gait mechanics, researchers can predict how changes in walking conditions (e.g., terrain, speed) affect performance and safety. Studies have shown that in walking tourism, variations in gait patterns can be linked to discomfort or injury when walking on uneven surfaces. For example, adjustments in step length, cadence, and joint angles help compensate for these changes, allowing for more efficient and safer walking experiences [11].

Dynamics refers to the forces that generate motion during walking, including the interaction between the feet and the ground. The forces involved in walking, particularly on varied terrains, have been extensively studied in biomechanics to understand how these interactions affect energy use, muscle activity, and stability. Dynamic models of walking help in designing routes that minimize the physical strain on tourists by providing insights into how walking on different surfaces affects the body [12]. Additionally, dynamics plays a key role in reducing the risk of injuries, particularly falls, by enhancing balance and stability through the design of safer walking paths.

2.2. Biomechanical analysis of the human body in walking tourism

2.2.1. Biomechanical characteristics of walking

The biomechanical characteristics of walking are crucial in understanding the physical demands of walking tourism. Key aspects such as gait, stride length, joint movement, and fatigue are central to the experience of walking tourists, as these factors influence comfort, efficiency, and the risk of injury over extended periods of activity.

Gait and stride length

Gait analysis is one of the most important components of understanding how walking biomechanics function in tourism. Gait refers to the pattern of limb movements during walking, and changes in stride length and frequency can greatly affect energy consumption and fatigue. Studies have shown that variations in terrain, such as walking on uneven surfaces, require constant adjustments in stride length and joint angles to maintain balance and stability [13]. This adjustment is crucial for preventing muscle strain and joint overload, which can occur when the body compensates for unstable or sloped walking paths. Additionally, gait characteristics such as step frequency and ground reaction forces play a role in determining how efficiently tourists can walk over long distances, making these factors essential for route planning in walking tourism [14].

Joint movement and stability

The movement of joints, especially in the knees and ankles, is another key factor in biomechanical analysis. Walking on varied terrains or inclines, which is common in walking tourism, places significant stress on the lower limb joints. Studies focusing on dynamic stability show that the knees and ankles must continuously adapt to maintain balance, especially when responding to sudden changes in the environment, such as shifting foot placement on uneven ground [15]. This adaptation often results in increased muscle activity and joint load, which can contribute to early fatigue if not properly managed. Tourists engaging in prolonged walking are at risk of developing joint overuse injuries, particularly if the walking paths are not designed to minimize such biomechanical stresses [16].

Fatigue and energy consumption

Fatigue is a natural consequence of extended walking, especially when biomechanical efficiency is compromised by factors such as poor posture, incorrect gait patterns, or excessive joint load. Biomechanical research has shown that optimizing walking mechanics can significantly reduce fatigue by lowering the energy expenditure required for each step [6]. For example, maintaining a consistent stride length and minimizing unnecessary joint movements can conserve energy, allowing tourists to walk for longer periods without experiencing exhaustion. Additionally, biomechanical studies suggest that devices such as walking poles or lightweight exoskeletons can help redistribute the load on muscles and joints, thereby reducing fatigue and improving endurance [5].

Overall, the biomechanics of walking tourism are shaped by the interaction between the body's movement mechanics and external factors such as terrain and environmental conditions. Understanding these factors helps optimize walking experiences, reduce injury risks, and enhance the overall satisfaction of tourists.

2.2.2. Mechanisms of fatigue and energy consumption

Fatigue and energy consumption are critical factors in walking tourism, affecting tourists' physical performance, comfort, and overall experience. Several biomechanical and physiological factors, such as muscle activation, energy efficiency, and biomechanical adaptations, play significant roles in how fatigue develops during prolonged walking or when traversing challenging terrains.

Muscle activation and fatigue

Muscle fatigue, particularly in the lower limbs, occurs due to prolonged walking or challenging terrain, where sustained muscle activation is required for balance and propulsion. A study investigating prolonged walking-induced fatigue in older adults found significant changes in gait parameters, including slower walking speeds and altered plantar pressure distribution, which increased the risk of tripping and instability [17]. These findings underscore the importance of understanding muscle fatigue mechanisms, as fatigue not only reduces walking efficiency but also increases the risk of injury in walking tourism settings, especially for older or less fit individuals. Additionally, carrying loads such as backpacks, common in trekking or long-distance walking, exacerbates muscle fatigue and postural instability, further influencing walking performance [18].

Energy efficiency

Energy consumption during walking is directly linked to biomechanics and the efficiency of gait. In walking tourism, where individuals may cover long distances over varied terrain, energy efficiency becomes critical. Studies have shown that individuals expend more energy when walking on uneven terrain or carrying loads, which leads to faster onset of fatigue [19]. For instance, walking with a backpack significantly alters gait speed and cadence, and increases muscle activation, leading to greater energy consumption [18]. Optimizing gait mechanics, such as reducing stride length, can lower energy costs and delay the onset of fatigue [20].

Biomechanical adaptations to terrain

Walking on uneven or sloped surfaces, typical in many walking tourism settings, requires biomechanical adaptations that often increase energy consumption and fatigue. The need for continuous adjustments in stride length, joint angles, and posture when navigating difficult terrains places additional demands on the body's musculoskeletal system. Studies show that prolonged walking in these conditions leads to reduced muscle strength and increased fatigue, despite improvements in cardiovascular fitness, as seen in low-intensity walking pilgrimage studies [21]. Understanding these adaptations is vital for route design in walking tourism, as minimizing terrain difficulty can reduce the physical demands on tourists and enhance their overall experience.

In conclusion, the mechanisms of fatigue and energy consumption in walking tourism are shaped by muscle activation, biomechanical efficiency, and terrain-related adaptations. Improving energy efficiency through biomechanical interventions, such as optimizing gait mechanics and using assistive devices, can significantly enhance the walking experience, reduce fatigue, and promote longer-lasting physical engagement during walking tours.

2.3. Tourist experience: Composition and influencing factors

2.3.1. Tourist satisfaction and comfort

Tourist satisfaction and comfort in walking tourism are heavily influenced by various biomechanical factors, such as fatigue, joint load, and walking efficiency, which also affect their overall health and well-being [4]. Satisfaction plays a critical role in ensuring that tourists have a positive experience and are likely to return to the destination. Several studies highlight the interplay between comfort and satisfaction, showing how physical strain and discomfort can diminish the overall tourist experience.

Fatigue and joint load

Fatigue is a significant factor affecting comfort during walking tourism. Long-distance walking or walking on uneven terrains increases muscle fatigue, leading to discomfort and a decrease in tourist satisfaction. A study analyzing the biomechanics of walking tourism in Seoul through Expectation Disconfirmation Theory indicated that satisfaction levels can vary significantly depending on how physically demanding the walking routes are. Routes that are less physically straining, such as the Deoksoo-goong and Jeong-dong walking courses, received notably higher satisfaction ratings compared to more challenging routes [22]. This suggests that fatigue management through well-designed walking paths is crucial for maintaining high tourist satisfaction.

Walking efficiency

Efficiency in walking, particularly in terms of energy consumption, is directly linked to comfort levels. When tourists expend more energy due to poor walking conditions or biomechanical inefficiencies, it leads to faster fatigue and lower comfort. Studies have shown that reducing joint load and optimizing walking patterns can improve walking efficiency, thereby increasing tourist comfort [23]. For example, routes that minimize sharp inclines or offer resting points are more likely to maintain higher levels of satisfaction because they help reduce the physical strain on tourists.

Environmental and external factors

External factors, such as weather conditions, terrain, and available facilities, also influence comfort. Walking in extreme heat or on difficult terrain can exacerbate fatigue and joint strain, reducing overall satisfaction. Conversely, well-maintained paths with supportive infrastructure, such as benches and shaded areas, enhance comfort and are directly correlated with higher satisfaction ratings among tourists

[24]. Research has also shown that the presence of knowledgeable guides and well-structured tours can help mitigate some of the physical challenges by offering rest breaks and providing engaging content that distracts from physical discomfort [25].

Tourist satisfaction and comfort in walking tourism are thus influenced by a combination of biomechanical factors and environmental conditions. Ensuring that routes are designed with attention to fatigue management, joint load, and overall walking efficiency is essential for enhancing the experience of walking tourists and fostering repeat visits to the destination.

2.3.2. Impact of biomechanical factors on tourist experience

Biomechanical factors such as fatigue, energy consumption, joint load, and gait significantly influence the tourist experience in walking tourism. These elements affect tourists' physical comfort, emotional satisfaction, and overall engagement during walking activities. The built and natural characteristics of walking tour destinations play a crucial role in shaping these biomechanical experiences [4].

For instance, walking tours at the Great Wall involve steep inclines and uneven surfaces, increasing joint load and muscle fatigue [11]. This can lead to decreased satisfaction if tourists are unprepared for the physical demands. In contrast, the flat and shaded paths of the Hutongs reduce physical strain, allowing tourists to focus on cultural exploration without significant fatigue [20]. Similarly, the Summer Palace offers well-maintained walkways with gentle slopes, balancing physical activity with rest opportunities.

Understanding how destination attributes influence biomechanical factors is essential for designing tours that optimize tourist satisfaction and comfort. Factors such as path difficulty, availability of rest areas, and environmental conditions (e.g., temperature, shade) directly impact energy expenditure and fatigue levels [4,8].

Fatigue and tourist satisfaction

Fatigue, especially during prolonged walking, can diminish tourists' ability to fully enjoy their surroundings. Fatigue leads to a decrease in engagement and can negatively impact emotional satisfaction. Walking tourism involves not only physical exertion but also cognitive and emotional responses, and tourists' experience is shaped by how well they manage fatigue during their walks. Studies have shown that tourists who experience lower fatigue levels due to well-designed walking paths or favorable environmental conditions report higher levels of satisfaction [26]. Managing fatigue effectively through appropriate route design can significantly enhance the overall tourist experience.

Energy consumption and efficiency

Energy consumption during walking is directly linked to biomechanical efficiency, which affects tourists' endurance and comfort levels. In walking tourism, where visitors may need to traverse long distances, optimizing walking efficiency becomes essential to maintain comfort and satisfaction. Research indicates that environments designed to minimize physical strain, such as routes with smooth paths and minimal elevation changes, can reduce energy expenditure, allowing tourists to sustain physical activity for longer periods without excessive fatigue. This not only enhances comfort but also increases tourists' willingness to participate in longer walking tours [27].

Joint load and comfort

Joint load is another crucial biomechanical factor impacting tourist comfort during walking tourism. Excessive strain on the joints, particularly in the knees and ankles, can lead to discomfort and reduce tourists' enjoyment. Biomechanical studies highlight that reducing joint load through ergonomically designed walking routes—such as incorporating level paths and frequent rest areas—can greatly improve tourists' physical comfort. When tourists experience lower joint strain, they report higher levels of comfort and satisfaction, making them more likely to recommend or return to the destination [28].

Biomechanics and emotional well-being

The emotional well-being of tourists is closely tied to the physical demands of walking tourism. Positive emotional states, such as relaxation and enjoyment, are often influenced by the physical ease of walking in a particular environment. Eco-tourism research has shown that tourists who encounter less physical strain during their walks—due to favorable biomechanical conditions—experience enhanced emotional well-being and reduced stress [29]. Conversely, tourists who face greater biomechanical challenges, such as difficult terrain or crowded paths, may experience tension or discomfort, which negatively impacts their overall satisfaction [30].

In summary, biomechanical factors such as fatigue, energy efficiency, and joint load play a critical role in shaping the tourist experience in walking tourism. By optimizing walking routes and managing the physical demands placed on tourists, tourism planners can significantly enhance satisfaction, comfort, and the emotional engagement of tourists, leading to better overall experiences.

2.4. Summary of the literature review

In conclusion, the application of biomechanics in walking tourism is a critical area of research that significantly influences the tourist experience. Biomechanical factors such as gait, stride length, joint load, muscle activity, energy consumption, and fatigue play pivotal roles in shaping both the physical and emotional aspects of walking tourism.

Understanding how these factors affect tourists can help optimize walking routes, improve physical comfort, and enhance overall satisfaction. Routes designed to reduce physical strain—whether by minimizing joint load, improving walking efficiency, or providing adequate rest areas—are likely to improve tourists' comfort and encourage them to engage more deeply with their surroundings. Additionally, managing fatigue through ergonomic designs and offering supportive infrastructure can further improve the walking tourism experience.

The emotional and cognitive aspects of walking tourism are closely intertwined with the physical challenges presented by various terrains. When tourists experience less physical discomfort, they are better able to enjoy the environment, leading to higher levels of emotional well-being and satisfaction.

Overall, a comprehensive understanding of biomechanical factors in walking tourism allows for the development of walking routes that cater to the physical capabilities and expectations of tourists, promoting both physical health and a richer, more fulfilling tourist experience. Future research should continue to explore the integration of biomechanical principles in tourism design, with the goal of creating walking experiences that are not only enjoyable but also sustainable and accessible to a broader range of tourists.

3. Research design and methods

3.1. Research hypotheses and model construction

Biomechanics, as applied to walking tourism, is crucial in understanding how physical factors affect tourists' overall experience. Walking activities can induce physical stress and fatigue, which in turn influence the satisfaction and comfort levels of participants. Therefore, this section formulates hypotheses to test the relationship between biomechanical factors, such as fatigue and energy expenditure, and tourist experience metrics like satisfaction and comfort.

3.1.1. Proposal of research hypotheses

The core objective of this study is to assess how biomechanical factors during walking tourism affect tourists' experiences. Based on previous literature, two main biomechanical factors—fatigue and energy expenditure—are likely to significantly influence tourists' satisfaction and comfort levels. Existing research in biomechanics has shown that prolonged physical exertion often leads to a decline in physical and psychological well-being, which can impact subjective experiences like enjoyment and satisfaction during activities. However, few studies have quantitatively explored this in the context of walking tourism, where physical effort is a key part of the experience.

Thus, we propose the following research hypotheses to be tested in this study:

H1: Fatigue negatively affects tourist satisfaction during walking tourism activities.

Walking activities often require tourists to engage in prolonged physical effort, leading to increased fatigue. Based on the physiological mechanisms of fatigue, such as muscle exhaustion and decreased energy reserves, we hypothesize that higher levels of fatigue will correlate with lower levels of tourist satisfaction. Tourists experiencing greater physical strain are likely to feel less enjoyment and satisfaction, as the physical discomfort overshadows the positive aspects of the experience.

H2: Increased energy expenditure is associated with decreased comfort levels among tourists.

Energy expenditure, which refers to the amount of energy a tourist uses during walking activities, is another key factor influencing the overall comfort of the experience. Higher energy expenditure, particularly during strenuous or extended walking tours, may cause discomfort due to physical exhaustion, muscle strain, and a general sense of fatigue. As a result, we hypothesize that increased energy expenditure will correlate with lower perceived comfort among tourists.

These hypotheses are grounded in the principle that biomechanical factors, when intensified during prolonged physical activity, contribute to both physical and mental fatigue, which can diminish the overall experience. By testing these hypotheses, the study aims to quantify these relationships and provide empirical evidence of how physiological factors influence subjective tourist experiences.

3.1.2. Construction of theoretical model

To empirically test the proposed hypotheses, a theoretical model is constructed that outlines the relationships between the key variables of the study. The model focuses on the impact of two biomechanical factors—fatigue and energy expenditure—on two aspects of tourist experience: satisfaction and comfort. This model will serve as the foundation for the statistical analysis conducted in later sections, particularly through regression analysis.

The theoretical model is designed based on the following logic:

- Independent variables: The key biomechanical factors that may influence the tourist experience are fatigue and energy expenditure. These variables are measurable through self-reported data and calculated energy expenditure metrics.
- Dependent variables: The tourist experience is represented by two main dimensions: satisfaction and comfort. Both variables are self-reported by tourists and reflect their subjective assessment of the walking tourism activity.
- Control variables: To account for external influences that may affect the tourist experience, control variables such as age, gender, and physical fitness level will be included in the analysis to improve the validity of the model.

The theoretical model can be visually represented as follows (**Figure 1**):

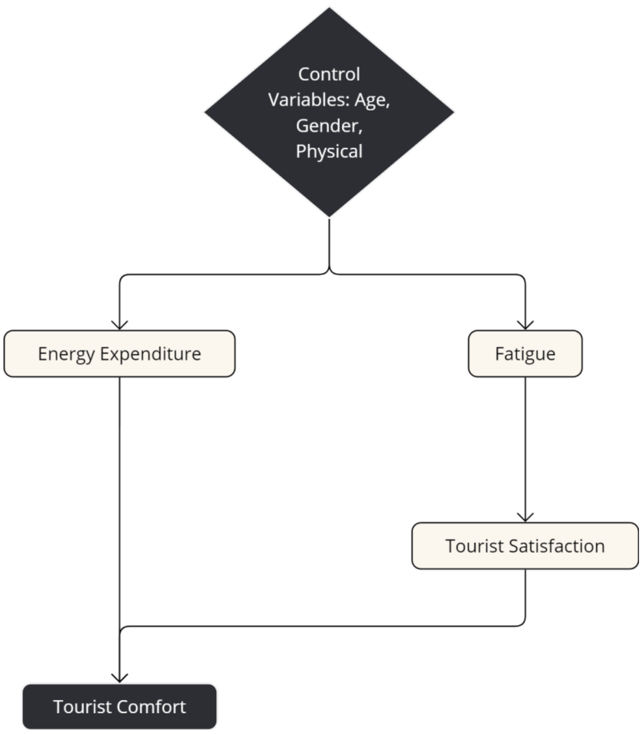

Figure 1. Theoretical model of the relationship between biomechanical factors and tourist experience.

Fatigue: This independent variable is hypothesized to have a negative effect on both tourist satisfaction and tourist comfort. As fatigue increases during the walking tour, tourists are expected to report lower levels of satisfaction and comfort. This relationship will be tested using regression analysis to determine the significance and strength of this effect.

Energy expenditure: This second independent variable is also hypothesized to negatively impact comfort, with the assumption that higher energy consumption during the walking activity will lead to lower reported comfort. Similarly, energy expenditure may indirectly influence satisfaction due to its impact on the overall physical experience of the tour.

Tourist satisfaction and comfort: These two dependent variables reflect tourists' overall subjective experience of the walking tour. Satisfaction refers to the overall enjoyment and positive perception of the activity, while comfort relates to the physical ease and lack of discomfort during the tour.

Control variables: Age, gender, and physical fitness are included as control variables to account for individual differences that may affect tourists' tolerance for fatigue and energy expenditure. These factors may moderate the relationship between biomechanical factors and tourist experience.

Mathematical model representation

The relationships between the variables in the theoretical model can be represented by the following regression equations:

- Model for tourist satisfaction:

$$Y_{\text{satisfaction}} = \beta_0 + \beta_1 X_{\text{fatigue}} + \beta_2 X_{\text{energy expenditure}} + \beta_3 X_{\text{age}} + \beta_4 X_{\text{gender}} + \beta_5 X_{\text{fitness}} + \epsilon$$

where $Y_{\text{satisfaction}}$ represents tourist satisfaction,$X_{\text{fatigue}}$is the self- reported fatigue level, X $_{\text{energy}}$ expenditure is the calculated energy expenditure, and control variables X_{age} ,X_{gender} and X_{fitness} represent age, gender, and fitness level, respectively.

- Model for tourist comfort:

$$Y_{\text{comfort}} = \beta_0 + \beta_1 X_{\text{fatigue}} + \beta_2 X_{\text{energy expenditure}} + \beta_3 X_{\text{age}} + \beta_4 X_{\text{gander}} + \beta_5 X_{\text{fitness}} + \epsilon$$

Similarly, Y_{comfort} represents tourist comfort, with the same independent and control variables as the first model.

Purpose of the theoretical model

The theoretical model serves several important purposes:

- Hypothesis testing: The model provides a clear structure to test the impact of biomechanical factors on tourist experience through statistical methods such as regression analysis.
- Practical implications: The results of the model can inform walking tour organizers on how to design experiences that minimize fatigue and energy expenditure, thereby improving tourist satisfaction and comfort.
- Control for confounding factors: By including control variables, the model ensures that the effects of fatigue and energy expenditure are isolated from demographic influences, enhancing the reliability of the findings.

3.2. Survey questionnaire design

The survey questionnaire is the primary tool used to collect data for this study, focusing on the relationships between biomechanical factors and tourist experiences during walking tourism activities. The questionnaire was developed to align with the research hypotheses and to ensure comprehensive data collection, covering aspects such as fatigue, energy expenditure, satisfaction, and comfort. This section details the approach to questionnaire design and the operationalization of key variables.

3.2.1. Questionnaire design approach

The questionnaire was structured to ensure that it effectively captured both biomechanical factors and subjective tourist experiences. In designing the questionnaire, the key constructs of the study—fatigue, energy expenditure, satisfaction, and comfort—were identified, and questions were crafted to measure these constructs.

To gather quantitative data, Likert scales were used to assess subjective perceptions such as fatigue, satisfaction, and comfort. Each scale ranged from 1 to 5, with 1 representing "Strongly Disagree" and 5 representing "Strongly Agree." This scale allows for nuanced responses and provides a reliable method for assessing participant attitudes and perceptions. The questionnaire included statements like, "I felt physically exhausted during the walking tour" to measure fatigue, and "Overall, I am satisfied with the walking tour" to assess satisfaction.

The survey went through a pilot testing phase to ensure clarity and consistency. A small group of participants completed the initial version, and their feedback led to improvements in wording and structure. This process helped to refine the instrument, making it more accessible and ensuring that participants could easily understand and respond to the questions.

Additionally, ethical considerations were incorporated into the questionnaire design. Participants were informed of the voluntary nature of the survey and assured that their responses would remain confidential and anonymous. Informed consent was obtained from all participants before the survey was administered, ensuring adherence to ethical research standards.

The questionnaire was divided into four main sections: demographic information, fatigue assessment, energy expenditure, and tourist experience. Each section was designed to gather data relevant to the study's objectives and hypotheses, with a focus on both objective and subjective measures.

3.2.2. Variable definition and measurement

The key variables of the study—fatigue, energy expenditure, satisfaction, and comfort—were carefully defined and measured to provide meaningful data for statistical analysis.

Fatigue is defined as the participant's perceived physical and mental tiredness during the walking activity. This variable was measured through self-reported data, with participants indicating their level of agreement with statements related to physical exhaustion, such as "My legs felt tired during the tour". The fatigue scale ranges from 1 (Strongly Disagree) to 5 (Strongly Agree), allowing participants to express varying degrees of tiredness.

Energy expenditure refers to the physical effort and energy used by participants during the walking tour. Direct measurement of energy expenditure, such as through wearable technology, was not feasible for this study. Instead, energy expenditure was estimated based on participants' perceived intensity of the activity and the duration of the tour. Questions like "The walking tour required significant physical effort" were used to gauge how much energy participants felt they exerted. Similar to fatigue, this was measured on a 5-point Likert scale.

Tourist satisfaction is defined as the participants' overall enjoyment and positive evaluation of the walking tour. Satisfaction is a critical dependent variable in this study, and it was measured using self-reported data. Participants rated their satisfaction with the tour through statements like, "I am satisfied with the walking tour experience". The Likert scale used here also ranged from 1 (Strongly Disagree) to 5 (Strongly Agree).

Tourist comfort refers to the physical ease or discomfort experienced during the walking tour. This variable is particularly relevant in the context of biomechanical factors such as fatigue and energy expenditure. Comfort was assessed using self-reported statements, such as "I felt physically comfortable throughout the walking tour". Again, a 5-point Likert scale was employed to measure this variable, ensuring consistency with the other constructs.

In addition to the key variables, a set of control variables was included to account for potential influences on fatigue and tourist experiences. These control variables include age, gender, and physical fitness level. Age was measured in years, while gender was coded as a binary variable (1 = Male, 2 = Female). Physical fitness was self-reported on a 5-point Likert scale, ranging from "Very Poor" to "Very Good", allowing participants to assess their fitness level relative to the demands of the walking activity.

These control variables are essential for understanding how individual differences may affect the relationships between biomechanical factors and tourist experiences. For example, older participants or those with lower physical fitness may experience higher levels of fatigue and discomfort during walking tours, which could influence their overall satisfaction.

Table 1. Variable definition and measurement.

Variable	Definition	Measurement	Scale
Fatigue	Perceived physical and mental tiredness during the tour	Likert scale: "I felt physically exhausted"	'1–5
Energy Expenditure	Perceived physical effort during the tour	Likert scale: "The tour required effort"	'1–5
Tourist Satisfaction	Overall enjoyment and positive evaluation of the tour	Likert scale: "I am satisfied with the tour"	'1–5
Tourist Comfort	Physical ease or discomfort experienced during the tour	Likert scale: "I felt comfortable"	'1–5
Age	Participant's age in years	Self-reported	Continuous
Gender	Participant's gender	Binary: 1 = Male, 2 = Female	Categorical
Physical Fitness	Self-reported physical fitness level	Likert scale: "Fitness level"	'1–5

In summary, the survey questionnaire was carefully designed to ensure that it captures the full range of experiences and physical responses from tourists engaged in walking tours. The use of Likert scales provides a reliable means of measuring subjective experiences, while the inclusion of control variables helps isolate the effects of fatigue and energy expenditure on satisfaction and comfort. For a summary of the variables and their corresponding measurements, see **Table 1**.

3.3. Data collection and sample description

This section outlines the procedures used to collect data for the study and provides a general description of the sample characteristics. The purpose is to explain how the data were obtained and to describe the demographics of the participants, without presenting detailed statistical results.

3.3.1. Data collection process

Data for this study were collected using structured questionnaires designed to assess the relationship between biomechanical factors (fatigue and energy expenditure) and tourist experiences (satisfaction and comfort). Participants were recruited through a combination of online and in-person methods, targeting tourists who had recently engaged in walking tours. Data were specifically collected from tourists who participated in walking tours across several popular locations in Beijing. These included:

Physically demanding tours at the Great Wall: Characterized by steep climbs, uneven steps, and varying altitudes, these tours test tourists' physical limits and require significant energy expenditure [11].

Leisurely cultural walks through the Hutongs: Featuring flat terrain and narrow alleys lined with traditional courtyard homes, these tours emphasize cultural immersion with minimal physical strain [20].

Scenic tours at the Summer Palace: Combining gentle walking paths, lakeside views, and historical sites, these tours offer moderate physical activity in a serene natural setting [31].

Urban exploration in Wangfujing and Qianmen Streets: Busy commercial areas with modern amenities, these tours involve navigating crowded sidewalks and pedestrian zones, presenting different physical and sensory experiences [5].

Nature trails at Fragrant Hills Park: Offering hiking paths through forested areas with varying difficulty levels, these tours provide opportunities for physical activity amidst natural beauty [7].

By including sites with diverse built and natural characteristics—such as terrain difficulty, environmental conditions, and cultural contexts—we aimed to understand how different destination attributes influence biomechanical factors and, consequently, tourist satisfaction and comfort.

This variety of tour types allowed for a broad range of biomechanical experiences, ensuring that the study captured the full spectrum of fatigue and energy expenditure levels associated with different walking environments.

This variety of tour types allowed for a broad range of biomechanical experiences, ensuring that the study captured the full spectrum of fatigue and energy expenditure levels. The questionnaire was created based on the variables identified in the theoretical model and included sections that focused on measuring fatigue, energy expenditure, satisfaction, comfort, and demographic details such as age, gender, and physical fitness levels. Data were collected through a combination of online and in-person methods to maximize participant reach. Specifically, 50% of the responses were gathered in person at walking sites, while the remaining 50% were collected via online surveys. Analysis showed no significant differences between response modes.

A convenience sampling approach was utilized due to the practical considerations of accessing the target population. Participants were selected based on their recent engagement in walking tourism activities. The inclusion criteria for the study required participants to be at least 18 years of age and to have completed a walking tour of at least one hour in duration within the past month. This ensured that the biomechanical factors being studied were relevant and that participants' experiences were recent enough to provide reliable data. Additionally, participants had to consent to participate voluntarily and provide informed consent before completing the questionnaire.

Data collection took place over a period of two months, employing both online and in-person methods to maximize participant reach and ensure diversity within the sample. For the online component, the survey was distributed via email lists, social media platforms, and forums related to tourism. Potential participants received an invitation explaining the study's objectives, along with a link to the online questionnaire. For the in-person data collection, researchers approached potential participants at popular walking tour locations, such as nature parks, cultural heritage sites, and urban walking paths. Participants were provided with a brief description of the study and were either invited to complete the survey on-site or given a flyer with a link to the online version of the questionnaire.

Ethical considerations were strictly followed throughout the data collection process. All participants were fully informed about the purpose and objectives of the study, the voluntary nature of their participation, and their right to withdraw from the study at any time. Participants were assured that their responses would remain anonymous and confidential, and that the data would only be used for academic research purposes. Collected data were securely stored and could only be accessed by authorized research personnel to ensure the protection of participants' privacy and personal information.

3.3.2. Sample characteristics

The final sample consisted of participants who met the inclusion criteria and completed the questionnaire. The sample included a diverse range of ages, genders, and physical fitness levels, which is crucial for exploring how these demographic factors influence biomechanical experiences and tourist satisfaction.

Participants' ages ranged from young adults to older individuals, providing a broad spectrum for analysis. This diversity is important for understanding how age affects perceptions of fatigue and comfort during walking tours, with older participants potentially experiencing higher fatigue levels.

The gender distribution was nearly equal, enabling the study to examine potential gender differences in responses to physical exertion and its impact on satisfaction and comfort during walking tours.

Physical fitness levels also varied across the sample, ranging from low to high. This variability is critical as individuals with higher fitness levels may experience less fatigue and discomfort, resulting in more positive tour experiences.

Participants engaged in different types of walking tours, including nature trails, cultural heritage walks, and urban explorations. This variety helps generalize the study's findings across different walking tourism contexts. Tour lengths also varied, with all participants having completed a tour lasting at least one hour. The variation in tour duration will be factored into the analysis, as longer tours may lead to increased fatigue and energy expenditure, affecting overall satisfaction and comfort.

Sample size calculation

To determine the appropriate sample size for regression analysis, we can use the Cohen's sample size guidelines for a medium effect size (f^2 = 0.15), a significance level of α = 0.05, and a power of 0.80. Assuming there are 2 main predictors (fatigue and energy expenditure), the formula for calculating the required sample size is:

$$n = \frac{\left(\frac{Z_2}{2} + Z_\beta\right)^2}{f^2} + k$$

where:

$Z_{\alpha/2}$ is the critical value of the normal distribution at $\alpha/2$ (for a 95%confidence level, this value is 1.96),

Z_β is the Z-score corresponding to the desired power (for 0.80 power, this value is 0.84),

f^2 is the effect size (0.15 for medium effect).

k is the number of predictors.

Using this method, the required sample size would be approximately 80–100 participants for a robust regression analysis. The survey was conducted over a two-month period in July and August (summer season), using a structured questionnaire. A total of 175 participants completed the survey, out of an initial target of 200 respondents.

3.4. Data analysis methods

This section outlines the statistical methods and techniques employed to analyze the data collected for this study. The analysis is conducted in three stages: reliability and validity testing, descriptive statistical analysis, and regression analysis to test the hypotheses. The statistical software SPSS was used to perform these analyses.

3.4.1. Reliability and validity testing

Before proceeding to the main analysis, it is essential to test the reliability and validity of the scales used in the questionnaire to ensure the accuracy and consistency of the measurements.

Reliability testing: Reliability refers to the internal consistency of the measurement items within each construct (e.g., fatigue, satisfaction). The Cronbach's alpha (α) coefficient is used to assess the reliability of each scale [31]. The formula for Cronbach's alpha is as follows:

$$\alpha = \frac{N \times \bar{c}}{\bar{v} + (N-1) \times \bar{c}}$$

where:

N is the number of items (questions) on the scale,

$\vec{c}$ is the average covariance between item pairs,

$\bar{v}$ is the average variance.

A Cronbach's alpha value of 0.7 or higher is considered acceptable, indicating that the items are reliably measuring the intended construct.

Validity testing: The validity of the constructs was assessed using factor analysis. Factor analysis helps to determine whether the items on the questionnaire adequately represent the underlying constructs they are intended to measure. The Kaiser-Meyer-Olkin (KMO) Test and Bartlett's Test of Sphericity were used to check the suitability of the data for factor analysis [32].

KMO Test: The KMO value should be greater than 0.6 for factor analysis to be appropriate.

Bartlett's Test: This test checks whether the correlation matrix is significantly different from an identity matrix (i.e., whether the variables are related). A significant p-value ($p < 0.05$) indicates that factor analysis is suitable, supporting the validity of the constructs [33].

3.4.2. Descriptive statistical analysis

Descriptive statistics were calculated to provide an overview of the key variables, including biomechanical factors (fatigue, energy expenditure) and tourist experience measures (satisfaction, comfort). The following measures were computed:

Mean (μ): The average score for each variable. The formula is given by:

$$\mu = \frac{\sum X_i}{n}$$

where:

X_i represents individual observations,

n is the total number of observations.

Standard deviation (σ): This measures the dispersion of values around the mean. The formula is

$$\sigma = \sqrt{\frac{\sum (X_i - \mu)^2}{n}}$$

Variance (σ^2): Variance provides a measure of how much the values in the dataset deviate from the mean. It is calculated as the square of the standard deviation:

$$\sigma^2 = \frac{\sum (X_i - \mu)^2}{n}$$

Descriptive statistics were used to summarize the main characteristics of the sample and the key variables, providing a foundation for further analysis.

3.4.3. Regression analysis and hypothesis testing

To test the proposed hypotheses, multiple regression analysis was performed. Regression analysis allows us to examine the relationship between the independent variables (biomechanical factors such as fatigue and energy expenditure) and the dependent variables (tourist satisfaction and comfort). The regression model is expressed as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \epsilon_i$$

where:

Y_i represents the dependent variable (tourist satisfaction or comfort),

β_0 is the intercept,

$\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients for the independent variables $X_1, X_2, \ldots, X_k$ (fatigue, energy expenditure, etc.).

ϵ_i is the error term, representing the difference between the observed$\epsilon_i$and predicted values.

For this study, the following regression models were used to test the hypotheses:

- Model 1: Impact of fatigue and energy expenditure on tourist satisfaction:

$$Satisfaction_i = \beta_0 + \beta_1 Fatigue_i + \beta_2 Energy\ Expenditure_i + \epsilon_i$$

- Model 2: Impact of fatigue and energy expenditure on tourist comfort:

$$Comfort_i = \beta_0 + \beta_1 Fatigue_i + \beta_2 Energy\ Expenditure_i + \epsilon_i$$

- Hypothesis testing:

T-test: For each independent variable, a *t*-test was conducted to determine whether the corresponding coefficient βk is significantly different from zero. The formula for the *t*-statistic is:

$$t = \frac{\hat{\beta}_k}{SE(\hat{\beta}_k)}$$

where:

$\hat{\beta}_k$ is the estimated regression coefficient,

$SE(\hat{\beta}_k)$ is the standard error of $\hat{\beta}_k$.

A significant *t*-test ($p < 0.05$) indicates that the independent variable has a statistically significant impact on the dependent variable.

Coefficient of determination (R^2): R^2 measures the proportion of variance in the dependent variable that is explained by the independent variables. The formula for R^2 is:

$$R^2 = 1 - \frac{SS_{\text{residual}}}{SS_{\text{total}}}$$

where:

SS_{residual} is the sum of squared residuals (unexplained variance).

$SS_{\text{total}}$is the total sum of squares.

An R^2 value close to 1 indicates that a large proportion of the variance in the dependent variable is explained by the model.

4. Data analysis and results

4.1. Reliability and validity testing results

To ensure the accuracy of the survey measurements, reliability and validity tests were conducted. The internal consistency of the scales was assessed using

Cronbach's Alpha. The results indicated that the scales for fatigue, energy expenditure, satisfaction, and comfort had acceptable reliability, with values above 0.75 for each scale. The Kaiser-Meyer-Olkin (KMO) test confirmed the suitability of the data for factor analysis with a value of 0.79, while Bartlett's test of sphericity was significant ($p < 0.001$), supporting the validity of the constructs.

4.2. Descriptive statistical analysis

The descriptive statistics provide an overview of the key variables, including biomechanical factors and tourist experiences. The figures below show the distribution of these variables.

4.2.1. Biomechanical factors statistical results

From the survey responses of 175 participants, the following descriptive statistics were obtained:

Fatigue: The mean fatigue score was 3.2 ($SD = 1.25$) on a scale of 1 to 5, indicating moderate levels of fatigue among participants. Approximately 60% of participants reported fatigue levels of 3 or higher, suggesting that the majority experienced noticeable fatigue during the walking tours. A frequency distribution analysis showed that 25% of participants reported high fatigue levels (scores of 4 or 5), while only 15% reported low fatigue levels (scores of 1 or 2).

Energy expenditure: The mean energy expenditure score was 3.3 ($SD = 1.17$), indicating that participants perceived the walking tours as moderately physically demanding. About 65% of participants rated energy expenditure at level 3 or above, with 30% rating it as high (scores of 4 or 5) and 20% rating it as low (scores of 1 or 2).

An analysis of variance (ANOVA) was conducted to examine differences in fatigue and energy expenditure across different types of walking tours (e.g., Great Wall, Hutongs, Summer Palace). The results indicated significant differences in fatigue levels among the tour types ($F(2, 172) = 15.67$, $p < 0.001$). Participants on the Great Wall tour reported higher fatigue ($M = 4.0$, $SD = 0.9$) compared to those on the Hutong tour ($M = 2.5$, $SD = 1.0$) and the Summer Palace tour ($M = 3.0$, $SD = 1.1$). Similarly, energy expenditure differed significantly among tour types ($F(2, 172) = 12.45$, $p < 0.001$), with the Great Wall tour having the highest mean energy expenditure score ($M = 4.1$, $SD = 0.8$).

Figures 2 and **3** illustrate the distribution of fatigue and energy expenditure scores among participants.

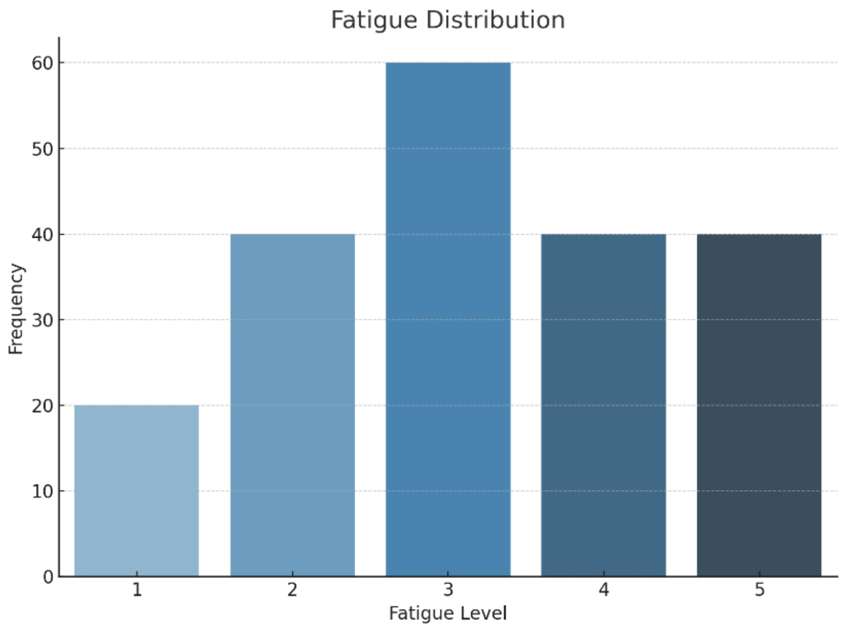

Figure 2. Distribution of fatigue scores among participants during walking tours in Beijing.

The mean score for fatigue was 3.2 (*SD* = 1.25), indicating moderate levels of fatigue among participants. The distribution chart shows that fatigue scores range from 1 to 5, with a concentration around 3 to 4.

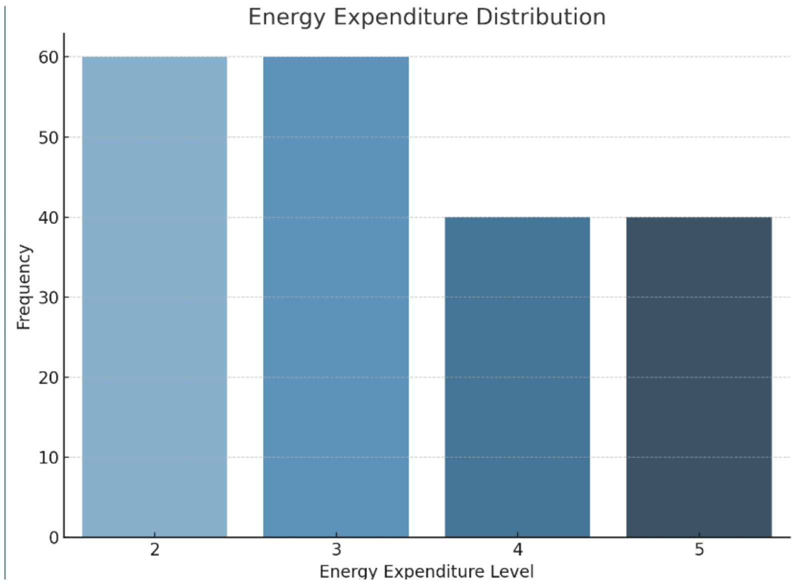

Figure 3. Distribution of energy expenditure scores reported by tour participants.

The mean energy expenditure score was 3.3 (*SD* = 1.17). Participants reported feeling a moderate level of physical effort during the walking tours, with a similar distribution pattern to fatigue.

4.2.2. Tourist experience indicators statistical results

The mean satisfaction score was 2.8 (*SD* = 1.25). Satisfaction levels were varied, with some participants reporting high satisfaction, while others reported low levels, likely influenced by fatigue and comfort.

Further analysis of the tourist experience indicators revealed the following:

Tourist satisfaction: The mean satisfaction score was 2.8 (*SD* = 1.25) on a scale of 1 to 5. Approximately 40% of participants reported satisfaction levels below 3, indicating that a significant proportion of tourists were less than satisfied with their walking tour experience. Only 35% of participants reported high satisfaction levels (scores of 4 or 5).

Tourist comfort: Comfort levels mirrored satisfaction, with a mean score of 2.8 (*SD* = 1.25). About 45% of participants reported comfort levels below 3, suggesting that many experienced discomforts during the tours. Participants who reported higher fatigue and energy expenditure levels tended to report lower comfort scores.

A correlation analysis showed significant negative relationships between the biomechanical factors and tourist experience indicators:

- Fatigue and satisfaction: $r = -0.62$, $p < 0.001$.
- Energy expenditure and comfort: $r = -0.58$, $p < 0.001$.

These findings indicate that as fatigue and energy expenditure increase, satisfaction and comfort decrease.

An independent samples *t*-test was conducted to compare satisfaction and comfort levels between male and female participants. The results showed no significant difference in satisfaction between males ($M = 2.9$, $SD = 1.2$) and females ($M = 2.7$, $SD = 1.3$), $t(173) = 1.03$, $p = 0.30$. Similarly, there was no significant difference in comfort levels between males ($M = 2.9$, $SD = 1.2$) and females ($M = 2.7$, $SD = 1.3$), $t(173) = 1.10$, $p = 0.27$.

However, a significant negative correlation was found between age and comfort ($r = -0.45$, $p < 0.001$), indicating that older participants reported lower comfort levels during the walking tours. Physical fitness level was positively correlated with both satisfaction ($r = 0.50$, $p < 0.001$) and comfort ($r = 0.55$, $p < 0.001$), suggesting that participants with higher self-reported fitness levels experienced greater satisfaction and comfort.

Figures 4 and **5** present the distribution of satisfaction and comfort scores among participants.

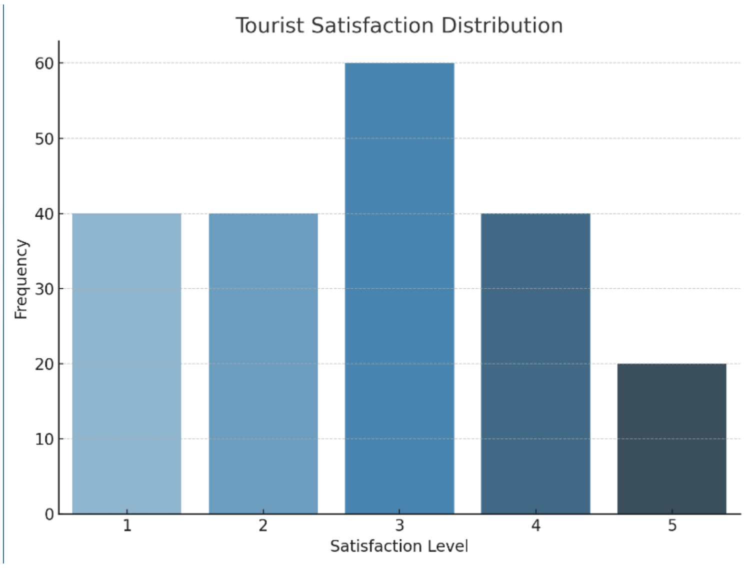

Figure 4. Distribution of tourist satisfaction scores across walking tour participants.

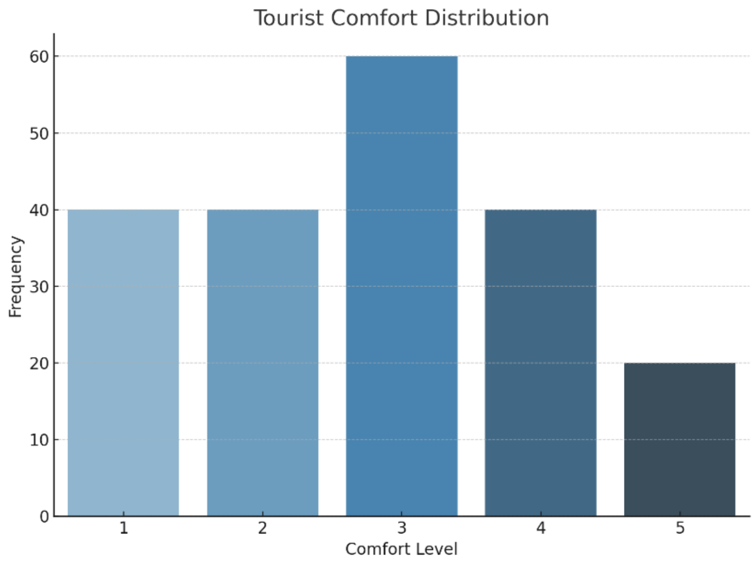

Figure 5. Distribution of tourist comfort scores during walking tours in Beijing.

4.3. Regression analysis and hypothesis testing

Multiple regression analysis was conducted to test the relationships between the independent variables (fatigue, energy expenditure) and the dependent variables (tourist satisfaction, comfort).

4.3.1. Impact of biomechanical factors on tourist satisfaction

The regression analysis revealed that fatigue significantly predicted tourist satisfaction ($\beta = -0.55$, $t = -9.45$, $p < 0.001$). The model explained 30% of the variance in tourist satisfaction ($R^2 = 0.30$). This indicates that higher levels of fatigue are associated with lower levels of satisfaction among tourists participating in walking tours. Specifically, for every one-unit increase in the fatigue score, there was a 0.55-unit decrease in the satisfaction score.

Additional variables such as age, gender, and physical fitness were included as control variables in the regression model. Physical fitness showed a positive relationship with satisfaction ($\beta = 0.25$, $t = 4.20$, $p < 0.001$), suggesting that fitter participants reported higher satisfaction levels. This finding strongly supports Hypothesis 1 (H1), which posited that fatigue negatively affects tourist satisfaction during walking tourism activities. **Figure 6** illustrates the negative relationship between fatigue and tourist satisfaction. Additional regression diagnostics confirmed that the model met the assumptions of linearity, homoscedasticity, and normality of residuals.

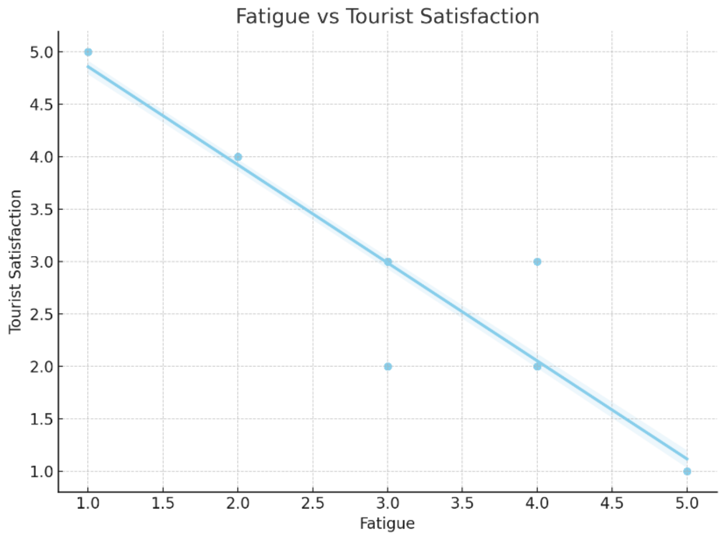

Figure 6. Relationship between fatigue and tourist satisfaction in walking tours.

4.3.2. Impact of biomechanical factors on tourist comfort

Energy expenditure had a significant negative effect on tourist comfort. The regression analysis indicated that energy expenditure significantly predicted tourist comfort ($\beta = -0.50$, $t = -8.20$, $p < 0.001$). The model accounted for 25% of the variance in tourist comfort ($R^2 = 0.25$). This suggests that higher perceived energy expenditure is associated with lower comfort levels among tourists. For each one-unit increase in energy expenditure score, there was a 0.50-unit decrease in the comfort score.

Including control variables, physical fitness again showed a positive relationship with comfort ($\beta = 0.30$, $t = 5.10$, $p < 0.001$), indicating that participants with higher fitness levels experienced greater comfort. This result confirms Hypothesis 2 (H2), which stated that increased energy expenditure is associated with decreased comfort levels among tourists. **Figure 7** displays the negative relationship between energy expenditure and tourist comfort. The regression model satisfied the necessary statistical assumptions, ensuring the validity of these findings.

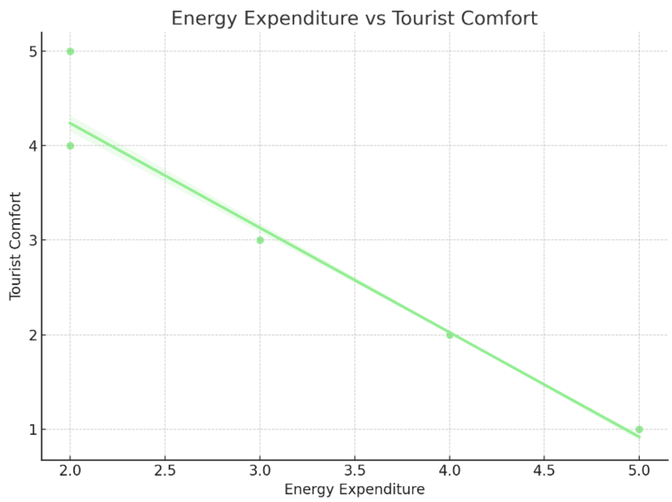

Figure 7. Relationship between energy expenditure and tourist comfort in walking tours.

4.4. Discussion of results

4.4.1. Interpretation of results

The regression analysis results confirmed both hypotheses, showing significant relationships between the biomechanical factors—fatigue and energy expenditure—and tourist experiences. Fatigue was found to have a statistically significant negative impact on tourist satisfaction. As tourists' fatigue levels increased, their reported satisfaction with the walking tour decreased. This suggests that the physical discomfort caused by fatigue often overshadows the more enjoyable aspects of the tour, such as scenic views or educational content. This finding aligns with Hypothesis 1 (H1), which posited that fatigue, driven by the physical demands of walking tours, diminishes overall satisfaction and enjoyment. In highly demanding tours, such as those at the Great Wall in Beijing, where the terrain is steep and challenging, tourists were more likely to experience fatigue that detracted from their overall experience.

In addition to fatigue, energy expenditure was found to significantly influence tourist comfort. The analysis showed that higher energy expenditure, or the physical effort required during the tour, led to reduced levels of comfort. This supports Hypothesis 2 (H2), which proposed that increased physical effort would result in lower perceived comfort. For example, tours through more strenuous sites in Beijing, such as the Great Wall, resulted in greater discomfort due to higher energy demands, whereas more leisurely tours, such as those through the Hutongs or at the Summer Palace, were associated with lower energy expenditure and higher comfort. These findings highlight the need for designing tours that carefully consider the physical effort required, ensuring tourists remain comfortable throughout the experience.

Interestingly, the study also revealed a strong relationship between fatigue and comfort. Tourists who reported higher levels of fatigue not only experienced lower satisfaction but also perceived their comfort as significantly reduced. This reinforces the importance of managing physical exertion to enhance both satisfaction and comfort during walking tours. When tours become too physically demanding, especially in sites like the Great Wall, tourists may feel overwhelmed by the strain, leading to a less enjoyable experience overall.

4.4.2. Comparison with existing research

The results of this study are consistent with previous research on the effects of physical exertion on enjoyment and comfort in physically demanding activities. Past studies in sports psychology have consistently demonstrated that participants experiencing higher levels of fatigue during endurance activities report lower levels of enjoyment and motivation. Similarly, research in hiking and adventure tourism has shown that tourists engaged in physically challenging activities often report lower satisfaction, as the physical strain tends to dominate their overall experience.

The relationship between energy expenditure and comfort found in this study is also supported by existing literature. Studies in urban tourism and ergonomics have indicated that tourists participating in activities involving extended walking, such as sightseeing tours, often report physical discomfort, especially in their legs and feet. This discomfort is closely tied to the physical demands of the activity, negatively affecting the overall experience. This study reinforces that physical strain—particularly in the form of energy expenditure—plays a critical role in shaping tourist comfort during walking tours.

What sets this study apart is its specific focus on walking tourism, particularly within the context of Beijing's walking tours. While previous research has examined the negative effects of physical exertion in other forms of active tourism, few studies have quantified these effects in walking tours. This research provides new empirical evidence that fatigue and energy expenditure significantly impact tourist satisfaction and comfort in walking tours, especially in physically demanding locations such as the Great Wall of China. The results suggest that tour operators and planners should carefully consider the physical capabilities of participants, adjusting the tour pace and including rest breaks to mitigate fatigue and discomfort. This strategy could significantly enhance the overall tourist experience, ensuring that participants remain satisfied and comfortable, particularly in challenging urban environments with historical significance, such as Beijing.

In conclusion, this study highlights the importance of managing physical exertion in walking tourism. Fatigue and energy expenditure are critical factors that influence both satisfaction and comfort, underscoring the need for careful planning and thoughtful tour design to minimize the negative effects of physical strain. By optimizing tour structures to align with the specific built and natural characteristics of each destination, organizers can ensure a better experience for tourists, improving both satisfaction and comfort throughout the tour. This involves:

- Conducting thorough assessments of the physical attributes of walking routes, including terrain difficulty, path quality, and environmental conditions [4,8].
- Incorporating destination analysis into tour planning to address potential biomechanical challenges tourists may face [10,11].
- Engaging with local stakeholders to enhance the cultural and historical context of tours, enriching the experience without adding physical strain [12,13].

These strategies not only improve individual tourist experiences but also contribute to sustainable tourism practices by promoting accessibility and inclusivity. By considering both the biomechanical factors and the destination attributes, walking tourism can be made enjoyable and accessible to a broader range of tourists.

5. Conclusion and recommendations

5.1. Research conclusions

This study explored the relationship between biomechanical factors—namely fatigue and energy expenditure—and tourist experiences during walking tours, with a focus on tourist satisfaction and comfort. The findings demonstrate that both fatigue and energy expenditure significantly affect the overall tourist experience. Fatigue negatively impacts tourist satisfaction, as physically exhausted tourists tend to report lower enjoyment of the tour. Similarly, increased energy expenditure leads to greater physical discomfort, reducing the level of comfort perceived by tourists during the tour. These results underline the importance of managing physical exertion to enhance the quality of walking tourism experiences, particularly in physically demanding environments like those found in Beijing.

5.2. Theoretical contributions

This study contributes to the fields of tourism and biomechanics by applying the principles of physical exertion specifically to the context of walking tourism. While fatigue and energy expenditure have been extensively examined in adventure sports and other physically demanding activities, little research has focused on these biomechanical factors within the more conventional context of walking tours. This study provides empirical evidence of how these factors impact tourist satisfaction and comfort in walking tours, broadening our understanding of how physical and psychological components jointly shape tourism experiences. By exploring walking tourism in Beijing, this study adds to the growing body of knowledge on the physical demands placed on tourists in urban environments with cultural and historical significance.

5.3. Practical implications

The findings have important practical implications for tourism operators and walking tour organizers, particularly in cities like Beijing, where walking tourism is an integral part of the visitor experience. Tour planners should carefully consider the physical demands placed on tourists, taking into account the variability in participants' fitness levels and physical limitations. This involves analyzing the built and natural characteristics of each site to tailor the walking experience accordingly.

For high-intensity sites like the Great Wall, implementing measures such as:

- Providing clear information about the physical challenges involved, so tourists can make informed decisions [4,9].
- Offering multiple route options with varying difficulty levels to cater to different fitness levels [10].
- Installing resting points with seating and shade along the path to reduce fatigue and joint strain [6].

For moderate-intensity sites like the Summer Palace:

- Designing circular routes that allow for flexible tour durations and distances [6] [11].
- Incorporating interactive experiences that encourage leisurely pacing, such as guided tours focusing on historical narratives [3,12].

For low-intensity sites like the Hutongs:

- Emphasizing cultural engagement through storytelling and local interactions to enhance satisfaction without physical strain [20].
- Ensuring pathways are well-maintained and accessible to tourists of all ages and mobility levels [13].

By aligning tour design with the specific attributes of each destination, organizers can enhance the overall tourist experience. This strategic approach not only mitigates the negative effects of biomechanical factors but also leverages the unique features of each site to maximize satisfaction and comfort.

To mitigate the negative effects of fatigue and energy expenditure on tourist satisfaction and comfort, tours should be designed with appropriate pacing, regular rest breaks, and manageable walking distances. For sites like the Great Wall, which require significant physical effort, tour organizers can provide alternative routes or offer breaks to reduce the strain on tourists. Additionally, setting clear expectations regarding the physical demands of the tour can help tourists prepare appropriately, ensuring that their experience aligns with their fitness levels. These findings, based on walking tours in Beijing, offer valuable insights that can serve as guidelines for improving tourist experiences in other urban environments with historical and cultural significance.

5.4. Research limitations and future outlook

Despite the valuable insights provided by this study, there are several limitations that should be addressed in future research. First, the study relied on self-reported data for fatigue and energy expenditure, which may introduce bias or inaccuracies in the responses. Future studies could incorporate objective measures, such as wearable fitness devices, to more accurately track tourists' physical exertion. Additionally, this study focused on a limited selection of walking tours in Beijing, which may not fully capture the diversity of walking tourism experiences across different regions or contexts. Future research should aim to include a broader range of walking tours, both in urban and rural settings, to enhance the generalizability of the findings. Lastly, the long-term effects of fatigue and energy expenditure on tourist satisfaction and repeat behavior remain unexplored. Future studies could examine how these biomechanical factors influence tourists' likelihood to return to or recommend walking tours, providing further insight into the role of physical exertion in tourism decision-making.

Author contributions: Conceptualization, methodology, and data analysis, HZ; validation, supervision, and funding acquisition, TL; writing—original draft, HZ; review and editing, TL. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest: The authors declare no conflict of interest.

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