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From Gym to Grid: Evaluating the Impact of COVID-19 on Saudi Gym-Goers' Willingness to Utilize Human Kinetic Energy for Sustainable Energy Generation

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Abstract: In the context of increasing sustainability through renewable energy utilization in Saudi Arabia, this study was motivated by the need to understand the impact of COVID-19 on gym-goers' attitudes and behaviors towards renewable energy generating using their human kinetic energy (HKE). A comparative analytical study was conducted using a pre-COVID-19 survey (n = 96) and a post-COVID-19 survey (n = 385) of gym-goers in Saudi Arabia. The surveys consisted of closed-ended Likert-type questions that measured participants' attitudes, behaviors, and willingness related to renewable energy and HKE generation. The results of the Chi-square test of independence showed that there was no significant difference in the participants' attitudes towards behaviors and awareness regarding renewable energy and HKE generation between the pre-COVID-19 and post-COVID-19 surveys. However, the study revealed an overall promising level of support for sustainable energy and HKE generation among gym-goers. This led to the conclusion that there is potential for the installation of sustainable HKE generation systems in gyms. The main implication of this finding is the need for greater education and awareness raising campaigns as well as incentives to support the implementation of renewable energy solutions. The research contributes to sustainable development and Saudi Vision 2030 by exploring potential opportunities for increasing the share of renewable energy in the overall energy mix and promoting sustainable development.

Keywords: COVID-19; gym; human kinetic energy; renewable energy; sustainability goals; sustainable development

Citation: Yusuf, N.; Fawzy, M.F. From Gym to Grid: Evaluating the Impact of COVID-19 on Saudi Gym-Goers' Willingness to Utilize Human Kinetic Energy for Sustainable Energy Generation. *Sustainability* **2023**, *15*, 10259. https://doi.org/10.3390/su151310259

Academic Editor: Elisa Marrasso

Received: 4 June 2023
Revised: 22 June 2023
Accepted: 27 June 2023
Published: 28 June 2023

1. Introduction

Renewable energy has become increasingly relevant in recent years as concerns about climate change and the depletion of fossil fuels have grown across the globe. An interesting area of exploration within this context, though not a major contributor to the overall energy balance, is human kinetic energy (HKE). This concept pertains to the energy generated by the movement of individuals and can be harnessed through various means that include the use of treadmills, bicycles, or other exercise equipment. People who are frequently visiting gymnasium centers for recreation or sports, also known as gym-goers, emerge as a potentially significant source of HKE because they engage in regular and intense physical activity. While research on harnessing HKE for renewable energy generation is still in its early stages, it holds the potential to contribute significantly to the renewable energy mix in various localities and regions. Offering intriguing possibilities for sustainability and energy awareness, HKE can promote a more informed approach to energy generation and consumption. However, the success of this approach depends on consumer willingness to

participate, and it is important to understand how this willingness may be impacted by various factors, such as the COVID-19 pandemic.

The energy generated through exercise, sports, and other forms of physical exertion can be harnessed and used to generate electricity for homes, businesses, and even communities. This type of energy generation is becoming increasingly popular as a means of generating renewable energy and reducing our dependence on non-renewable sources of energy. Still, the number of academic studies on the topic remains limited. In recent years, there have been numerous initiatives to harness HKE for energy generation [1,2]. Although most efforts cannot be traced beyond initial proposals, special exercise equipment has been developed that captures the energy generated by users and converts it into electricity [3]. This type of equipment is envisioned to be eventually installed in gyms, parks, and other public spaces, where people can exercise and generate electricity at the same time. Additionally, scholars highlighted the possibility of engineering wearable and implantable solutions that can be employed to power an individual's personal gadgets and devices [4]. The two most promising technologies that are being actively studied in the context of HKE include triboelectric and piezoelectric nanogenerators, both of which can be leveraged to create miniature devices that are capable of energy harvesting and conversion [4]. Apart from traditional generators, other proposed solutions include electrostatic energy converters as well as electromagnetic induction generators based on smart materials that change their properties in response to certain physical stimuli.

While HKE is currently not a significant source of renewable energy, it holds broader implications for sustainability by contributing to energy efficiency in specific settings and stimulating discussions about sustainability. However, its implementation is associated with certain challenges. For example, there are concerns about the cost of installing HKE systems, as well as the sustainability of the energy generated through these systems. There are also questions about the efficiency of HKE systems and their ability to generate significant amounts of electricity [5]. Although an individual might be receptive to using a small portable HKE-generating device, there are expected to be objections to implantable solutions and burdensome wearable frames or exoskeletons. On the other hand, researchers mention that insufficient output power and storage constraints create a bottleneck in the sphere's development until efficient HKE-generating equipment can be introduced to the public [1,6]. Although the energy conversion efficiency of HKE-based renewable energy generation is currently limited, with harvested energy levels reported in the microwatts range [5], there is ongoing research focused on improving the efficiency by altering physical and geometric parameters of harvesters. Some studies have reported generated electricity values ranging from 0.25 W to 7.4 [1,2,5], demonstrating the potential for this approach to contribute to the overall renewable energy mix if efficiency improvements can be achieved. Despite these challenges, HKE remains a promising area of research and development, and many believe that it will play an important role in our transition to a more sustainable energy future.

Sutainable Development Goals

The transition to renewable energy is essential to achieving sustainable development goals (SDGs) set by the United Nations. They represent a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity. Specifically, the SDGs include a clearly defined goal dedicated to ensuring access to affordable, reliable, sustainable, and modern energy for all (SDG7). From this standpoint, renewable energy is approached as a key solution to achieve this goal and to tackle issues related to climate change, energy security, and energy access [7,8]. Emphasizing the importance of renewable energy sources, including HKE, is crucial not only for achieving the SDGs, but also for transforming the global energy landscape. The growing urgency to combat climate change and reduce carbon emissions drives the need for innovative solutions like HKE, which presents an opportunity to diversify energy sources and promote a more sustainable future. The integration of HKE within gym environments and beyond can encourage

greater public engagement with renewable energy technologies, raise awareness of sustainable practices, and stimulate positive behavioral changes in energy consumption. In this regard, the research contributes to the ongoing global dialogue on renewable energy and its potential to reshape the way we generate and consume energy for a more sustainable world. By harnessing the energy generated during the course of natural human movements, this approach has the potential to increase access to energy, particularly in developing countries where traditional energy infrastructure is lacking [9]. From this perspective, the use of HKE as a source of renewable energy is an innovative approach that has the potential to contribute to the achievement of SDG7 as well as several other SDGs.

By reducing the dependence on fossil fuels, the use of HKE can also contribute to reducing greenhouse gas emissions and mitigating the impacts of climate change, which aligns with SDG13 on climate action. The traditional energy sector heavily relies on fossil fuels, which are major contributors to greenhouse gas emissions. The effort to utilize HKE as an alternative energy source creates conditions for the dependence on fossil fuels to be minimized, resulting in a substantial decrease in carbon dioxide and other greenhouse gas emissions [7]. This reduction contributes to global efforts to combat climate change and achieve the targets outlined in SDG13. Implementing HKE generation systems in gyms and other settings not only promotes clean energy generation, but also serves as an effective strategy to address the urgent need to transition to a low-carbon economy. By actively participating in the generation of renewable energy through their physical activities, individuals can contribute directly to mitigating climate change, making a tangible impact in achieving SDG13 [8]. For these reasons, the integration of HKE into the energy mix represents a crucial step toward a sustainable future and aligns with the broader objectives of the paper in promoting renewable energy, sustainable development, and climate action.

The adoption of HKE for renewable energy generation also aligns with SDG3 on good health and well-being, as it promotes physical activity while contributing to clean energy production. By incorporating HKE systems into gyms, individuals are motivated to embrace an active lifestyle, driven by the knowledge that their physical efforts are simultaneously generating clean energy. This integration creates an innovative and sustainable environment that encourages and rewards individuals for their commitment to fitness and sustainability. Regular exercise has been linked to numerous physical and mental health benefits, including improved cardiovascular health, enhanced mood and cognitive function, and reduced stress levels [1]. These positive effects contribute to overall well-being and align with the objectives outlined in SDG3. In the context of benefits mentioned above, HKE can also contribute to SDG12 on responsible consumption and production. For example, the utilization of HKE in gyms can foster a sense of environmental responsibility among individuals. By actively participating in the generation of renewable energy, gym-goers become stakeholders in the transition to a more sustainable future [8]. This engagement enhances their understanding of the environmental implications of energy consumption and fosters a sense of empowerment and ownership over their impact on the planet. The adoption of HKE as a renewable energy source further promotes responsible production by utilizing existing resources, specifically the energy generated during physical activities. As a result, the involvement in HKE-based energy generation allows individuals to reduce their reliance on traditional energy sources and contribute to a more circular and sustainable economy.

In the case of Saudi Arabia, the country adopted multiple goals concerning renewable energy as part of its Vision 2030 plan. The ambitious program includes targets for increasing the share of renewable energy in the overall energy mix and for reducing greenhouse gas emissions. Specifically, Saudi Arabia aims to produce 58.7 GW of renewable energy by 2030 while seeking to reduce the country's greenhouse gas emissions by 130 $MtCO_2e$ [10,11]. In this context, the use of HKE as a source of renewable energy is a potentially viable approach that can contribute to the achievement of the delineated goals. While the direct role of HKE in the country's energy production is currently negligible, even minor reductions in fossil fuel use can have a cumulative impact over time. By reducing the dependence on fossil

fuels, the use of HKE can contribute to decreasing greenhouse gas emissions and thus aligns with the main objective of Saudi Vision 2030 [12]. The implementation of HKE generation systems in gyms can raise awareness among the Saudi population while also helping to promote sustainable policies and programs. Overall, this study aims to provide insight into the impact of COVID-19 on consumer attitudes and behaviors toward HKE as well as their willingness to participate in renewable energy generation, which could inform the development of policies and programs for promoting the use of HKE. The contributions of HKE to the renewable energy production is limited in Saudi Arabia and other countries, but the understanding of attitudes towards this energy generation method is expected to have implication for sustainability studies, serving as a tangible demonstration of renewable energy generation and promoting energy efficiency. As a result, the country's authorities will be able to adequately prepare for the planned implementation of renewable energy generation in Saudi Arabia.

The primary reason for investigating the impact of the COVID-19 crisis on the willingness to utilize human kinetic energy for energy generation is to understand how external factors, such as a global pandemic, can influence public attitudes and behaviors toward innovative renewable energy solutions. The fitness industry, including gyms, has been significantly affected by the COVID-19 pandemic [13], and this research seeks to explore how these changes have influenced the willingness of gym-goers to participate in HKE-based renewable energy generation. By analyzing the impact of the pandemic on consumer attitudes and behaviors, the current study provides valuable insights that can guide the development of strategies to promote the adoption of HKE-based renewable energy generation in the post-pandemic world.

2. Literature Review

2.1. Consumer Attitudes and Behaviors towards Renewable Energy

Consumer attitudes and behaviors towards renewable energy are important factors in the transition to a more sustainable energy mix. A number of studies investigated consumer attitudes and behaviors towards renewable energy, with a focus on factors such as awareness, knowledge, willingness to pay, and willingness to participate in renewable energy generation [14]. One of the key findings from these sources is that consumer awareness and knowledge of renewable energy are generally low, as many consumers have a limited understanding of the benefits and potential associated with renewable energy [15,16]. For example, several international studies found that only a limited portion of participants tends to have a good understanding of renewable energy, while the majority show various misconceptions about the costs and feasibility of renewable energy [17,18]. A lack of knowledge can be a barrier to the adoption of renewable energy solutions. In comprehensive research focused on Greek consumers, Ntanos et al., demonstrated that only 28% of respondents were willing to cover the additional cost of renewable energy [19]. Although these observations are often tied to a lack of understanding of renewable energy's benefits, another concern pertains to the inadequate competitiveness of green energy solutions [20]. On the other hand, most researchers tend to agree that a certain group of consumers have a strong positive attitude towards renewable energy and are willing to cover the premium cost. The size of the group encompassing environment-conscious consumers varies from country to country [21]. Still, several authors showed that at least 10% are willing to pay a premium for renewable energy despite the supposed advantages of fossil fuels [22]. Factors that have been found to influence consumer attitudes and behaviors toward renewable energy positively include environmental concerns, government regulations, and social norms.

As evidenced by the overview of studies mentioned above, there are limited results on this specific topic. However, some authors have investigated the consumers' attitudes and behaviors towards renewable energy in general. A comprehensive categorization of 58 articles on the topic by El Haffar et al., highlighted the consumers' willingness to pay for green electricity, which includes renewable energy, while indicating that a significant

proportion of consumers are willing to pay a premium for green electricity [15]. Similarly, a study by Ayodele at al. found that Nigerian consumers who are environmentally conscious are more willing to adopt renewable energy solutions [21]. Another study in Greece focused on the factors that influence public perceptions towards renewable energy and found that environmental awareness, trust in the government, and personal values were significant factors [19]. Regarding the use of HKE for renewable energy generation specifically, there is a lack of research on consumer attitudes and behaviors. However, a study by Liobikienė and Dagiliūtė suggests that while consumers are generally willing to participate in HKE generation, the extent of their willingness is dependent on the perceived benefits of HKE generation [20]. In the given context, more research is needed on the use of HKE for renewable energy generation and consumers' attitudes and behaviors towards it.

2.2. Impact of COVID-19 on Industries and Consumer Behaviors

The COVID-19 pandemic had a significant impact on various industries, including the fitness industry. Many gyms closed or experienced reduced capacity due to social distancing measures. Multiple sources from different countries revealed that both private and public gyms were closed during the pandemic, while some only experienced reduced capacity [23–25]. The phenomenon resulted in a decline in the number of gym-goers leading to a gradual shift towards home-based workouts [26]. This has significant implications for the use of HKE for renewable energy generation, as the reduction in the number of gym-goers directly translates to a diminished potential for HKE to be generated. While most studies focused on the period of strictest anti-COVID-19 measures found that the number of gym-goers declined, several authors confirm that a significant portion of people unable to visit gyms reported doing more home-based workouts during the pandemic [27,28]. The shift towards home-based workouts also means that there are fewer opportunities for HKE to be captured and used for renewable energy generation. The described observations highlight the need for alternative methods of capturing HKE and finding ways to integrate it into renewable energy generation. In the given context, the impact of the pandemic on the fitness industry and how it has affected the potential for HKE generation is an important area for future research.

From another perspective, the emerging body of evidence suggests that the pandemic has led to an increase in consumer awareness due to growing concerns about the environment and sustainability [29]. These findings are likely connected to the increased focus on issues such as air quality and the need for clean energy during the pandemic [30]. However, Caputo and Reichert propose that the pandemic has led to a decrease in consumer willingness to participate in programs that involve HKE generation, such as those requiring the use of exercise equipment to generate electricity (2020) [31]. The shift towards home-based workouts and the reduced number of gym-goers during the pandemic may have contributed to this change. Furthermore, the COVID-19 pandemic resulted in a significant shift concerning consumer attitudes and behaviors toward energy consumption, with a study by García et al., demonstrating that the pandemic has led to an increase in energy consumption as people spend more time at home (2021) [32]. Research suggests that there is a need for further investigation of the impact of the pandemic on the fitness industry and consumer behavior toward renewable energy and HKE generation, as well as alternative methods of capturing HKE [33]. This can provide valuable insights for policymakers, energy providers, and researchers in the field of renewable energy and HKE.

2.3. Renewable Energy and Saudi Vision 2030

Saudi Vision 2030 is a plan for the future development of Saudi Arabia that aims to diversify the economy and promote sustainable development. A key pillar of this plan is the development of a sustainable energy sector, with ambitious targets for the development of renewable energy, including HKE [34]. The country's authorities launched a number of initiatives and programs to support the development of renewable energy. One of the most notable examples is the National Renewable Energy Program, an initiative

aimed at developing the technical and institutional capabilities needed to implement renewable energy projects [35]. As suggested by the available data, Saudi Arabia has yet to start investing in research and development in the field of HKE, with a focus on developing technologies to capture and convert HKE into electricity [36,37]. Overall, the literature review pointed to a multitude of sources of evidence reaffirming the importance of renewable energy in achieving sustainable development and its potential to contribute to the goals set by Saudi Vision 2030 [38]. Additionally, the Saudi government has set ambitious targets for the development of renewable energy, including HKE. For example, the Saudi Vision 2030 aims to increase the percentage of individuals engaging in regular exercise and athletic activities from 13% to 40% by promoting widespread participation in sports [39]. In line with this vision, Saudi Arabia has launched the National Renewable Energy Program managed by the Office of Renewable Energy Projects as part of the broader National Transformation Program [34]. This research aims to investigate how the attitudes and willingness of Saudi gym-goers to participate in HKE generation align with the goals set by Saudi Vision 2030 and contribute to sustainable development.

2.4. Research Question

The COVID-19 pandemic has had a significant impact on various industries and consumer behaviors. One industry that has been particularly affected is the fitness industry, with many gyms closing or experiencing reduced capacity as a result of social distancing measures [13]. In light of SDGs 3, 7, 12, and 13, it is also important to understand how the pandemic has affected consumer attitudes and behaviors toward HKE and renewable energy generation. Accordingly, the main objective of the current research is to investigate the impact of COVID-19 on gym-goers' willingness to participate in renewable energy generation using their HKE. This can be achieved by conducting a comparative study of consumer attitudes and behaviors before and after the pandemic. The research question guiding the investigative process is "How did COVID-19 impact gym-goers' willingness to participate in renewable energy generation using their HKE?" This question will be addressed by comparing the results of the pre-COVID-19 and post-COVID-19 surveys and testing the hypotheses. The study aims to provide insight into the potential of HKE for renewable energy generation and the impact of the COVID-19 pandemic on consumer willingness to participate in this approach.

2.5. Hypotheses

For the purpose of testing the research question, two hypotheses were formulated. The first hypothesis, H0, posits that there is no significant impact of COVID-19 on the gym-goers' willingness to participate in renewable energy generation using their HKE. The second hypothesis, H1, posits that there is a significant impact of COVID-19 on the gym-goers' willingness to participate in renewable energy generation using their HKE. These hypotheses will be tested using inferential statistics, such as the Chi-square test, to compare the results of the pre-COVID-19 and post-COVID-19 surveys. The results of the statistical analysis will be used to determine whether the observed differences in the data are likely due to chance or whether they are statistically significant. The acceptance or rejection of the hypotheses will provide insight into the impact of the COVID-19 pandemic on consumer willingness to participate in renewable energy generation using HKE. The novelty of the delineated approach lies in the unique context of the COVID-19 pandemic and its impact on gym-goers' willingness to participate in HKE-based renewable energy generation. While previous research has explored the potential of HKE for renewable energy, this study is among the first to investigate the impact of the pandemic on gym-goers' willingness to participate in renewable energy generation using their HKE. By conducting a comparative analysis of pre-COVID-19 and post-COVID-19 survey data, the research provides valuable insights into the shifts in willingness to participate in HKE-based renewable energy generation resulting from the pandemic. Additionally, the study contributes to the understanding of how external factors, such as global crises, can

influence the adoption of innovative renewable energy solutions, offering implications for policymakers, industry stakeholders, and future research.

2.6. Novelty and Contribution of the Study

This study investigates the impact of the COVID-19 pandemic on gym-goers' attitudes and behaviors towards human kinetic energy as a potential source of renewable energy. The comparative analytical approach, using pre- and post-COVID-19 surveys, provides a unique perspective on how external factors can influence public attitudes towards innovative renewable energy solutions. The main research methods applied in the course of the research include a combination of descriptive statistics methods with inferential statistics. This research contributes to the field by offering valuable insights that can guide the development of strategies to promote the adoption of HKE-based renewable energy generation in the post-pandemic world. Highlighting the attitudes within a selected population, the results will help to inform the development and implementation of other renewable solutions and policies.

3. Methodology

The methodology was designed to obtain a comprehensive understanding of gym-goers' attitudes and behaviors towards HKE and renewable energy generation, particularly in the context of the COVID-19 pandemic. After developing a robust survey instrument that was carefully designed to capture a wide array of responses, we employed statistical analysis to interpret the data. As the methodological approaches were originally designed to be both flexible and adaptable, this proved instrumental in adjusting the design in response to the unforeseeable circumstances associated with the pandemic. A detailed breakdown of the applied methodology is presented in subsequent sections of this chapter.

3.1. Research Design

The study relies on two individual surveys, with the first survey being conducted before the outbreak of COVID-19 (pre-COVID-19 survey) and the second survey being conducted after the outbreak of COVID-19 (post-COVID-19 survey). Both surveys used closed-ended Likert-scale questions to measure participants' attitudes, behaviors, and willingness related to renewable energy and HKE generation. Furthermore, both questionnaires consisted of 19 similar questions, which had only minor semantical differences in the pre-COVID-19 and post-COVID-19 surveys. While the first set of questions focused on the demographics and diversity of the survey participants, the second segment concentrated on providing information about the participants' workout behavior inside the gym. The third section aimed to understand the participant's acceptance level of renewable energy in general and especially their willingness to produce/use renewable energy in daily life. Finally, the last section of the survey was designed to single out the participants' willingness to be part of the HKE used to generate renewable energy (RE) and what would motivate them to participate. In contrast to the first two segments including context-specific response options, the last two sections' responses were represented as a 1–3 range on the Likert scale.

Before the implementation of the surveys, a pilot study was conducted for the pre-COVID-19 questionnaire to ensure its validity. The pilot study was distributed to a group of participants who provided feedback, allowing us to make necessary modifications. Factor analysis was conducted to identify the key factors that contribute to the questionnaire responses. The Kaiser–Meyer–Okin (KMO) test was used to assess the adequacy of the sample size, and Promax rotation (with Kaiser normalization) was applied to re-rotate the solution and enable correlations between factors. The resulting key factors were identified to provide answers to the research problems.

As the post-COVID-19 survey fundamentally contained the same questions as the pre-COVID-19 survey, there was a significant degree of confidence in the validity of the questions based on the initial validation process. The study acknowledges the small sample size (96 pre-COVID-19 participants and 384 post-COVID-19 participants), which may limit

the generalizability of the findings to the wider population of gym-goers in Saudi Arabia. A larger sample size could potentially provide more representative results and increase the statistical power of the study. Additionally, the study used a convenience sampling method, which could introduce bias and affect the generalizability of the results. The obtained responses are also based on self-reported data, which may be subject to social desirability bias and may not accurately reflect the actual behavior of participants. These limitations should be considered when interpreting the results of the study.

3.2. Data Collection

Throughout the data collection process, the same style and approach in the two surveys was maintained to ensure consistency and validity across both questionnaires. Launched in October 2019, the initial pre-COVID-19 survey was not conducted with the foresight of the COVID-19 pandemic. Instead, it aimed to study the feedback regarding people's willingness to participate in harvesting their kinetic energy and utilizing their waste energy in gym settings. However, as the COVID-19 pandemic emerged during the data collection process, there was an opportunity to expand the scope of the research to assess the impact of the pandemic on consumer willingness to participate in human kinetic energy generation.

The COVID-19 pandemic has brought unprecedented changes in societal attitudes and behaviors. In the context of this study, it was important to investigate whether these changes extended to gym-goers' willingness to participate in HKE-based renewable energy generation. By comparing pre- and post-COVID-19 attitudes, we aimed to assess the impact of the pandemic on this specific aspect of renewable energy engagement. The resulting analysis was expected to provide valuable insights for policymakers and stakeholders in the renewable energy sector, which would help them to design and implement more effective strategies in the post-pandemic world.

Regarding the number of respondents for the pre- and post-pandemic surveys, it was not feasible to track the same participants due to the gap between the two surveys. The initial pre-COVID-19 survey was conducted in October 2019, while the post-COVID-19 survey was launched in after the pandemic had already disrupted people's lifestyles and changed their attitudes towards renewable energy. For these reasons, the researchers had to recruit a new set of respondents for the post-COVID-19 survey to reflect the changes in the population's behavior and perceptions.

3.3. Data Analysis

The data from the surveys were analyzed using several methods to compare the results and test the hypotheses. Specifically, a combination of descriptive statistics methods, such as the mean and frequency distribution, with inferential statistics allowed us to address the research question and test the hypotheses adequately [40]. Used to test the association between two ordinal variables, the Pearson Chi-square test of independence is a statistical method that helps to determine if there is a significant difference between the observed and expected characteristics of the two ordinal variables [41]. In the current study, the two ordinal variables are the responses to the survey questions from the pre-COVID-19 and post-COVID-19 surveys. Furthermore, the Chi-square test of independence is the appropriate choice for this study because the sample size is unequal, and the data are collected using Likert-type scales [42]. The Chi-square test is a non-parametric test and does not require the assumption of normality, which is often not met when working with ordinal data such as Likert-type scales [43]. The level of significance was set at $p < 0.05$, which is the commonly used level of significance in scientific research.

4. Results

The results of the data analysis revealed that there were no significant changes in the demographics, behavior, awareness, and willingness of the participants between the pre-COVID-19 and post-COVID-19 surveys. In the pre-COVID-19 sample, the majority of

the participants were between the ages of 25 and 44, with a relatively equal distribution of male and female participants. Although age distribution was comparable, a considerable increase in male participants to 91% can be noted for the second group. In both groups, the average exercising time for the participants was 8 h per week, with most participants engaging in more than two types of exercises. Although specific exercising behaviors and schedules varied between the two samples, these variations are not expected to have a considerable impact on the outcomes of the research. In other words, the demographics and behavior-focused data mostly helped to prove that participant groups are diverse and could be considered suitable candidates for RE generation via HKE.

To provide a better understanding of the demographics of gym-goers in Saudi Arabia, it is worth noting that according to a report by Mordor Intelligence, in 2019, there were approximately 1280 gym facilities in the country, with a projected growth rate of 8.37% from 2021 [44]. Furthermore, the report indicates that the majority of gym-goers in the country are aged between 18 and 24 years old, followed by those aged between 25 and 34 years old. In terms of gender, male gym-goers outnumber female gym-goers, with most visitors exercising for 1–2 h each week. It is worth noting that while the sample size of the current study was limited to 96 and 384 participants, the demographics of the participants were diverse and can be considered representative of the general population of gym-goers in the country. Therefore, the findings of the study can be used as a starting point for future research on the willingness of Saudi gym-goers to participate in HKE generation for renewable energy (Figures 1 and 2).

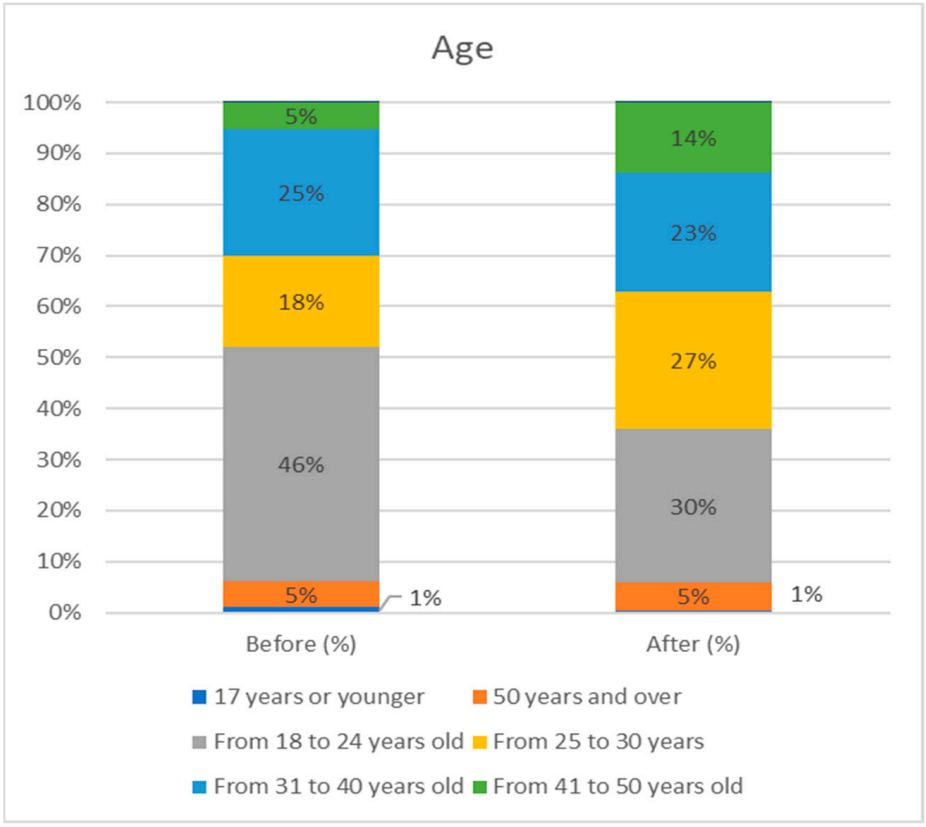

Figure 1. The frequency distribution of age for respondents in the pre-COVID-19 and post-COVID-19 surveys.

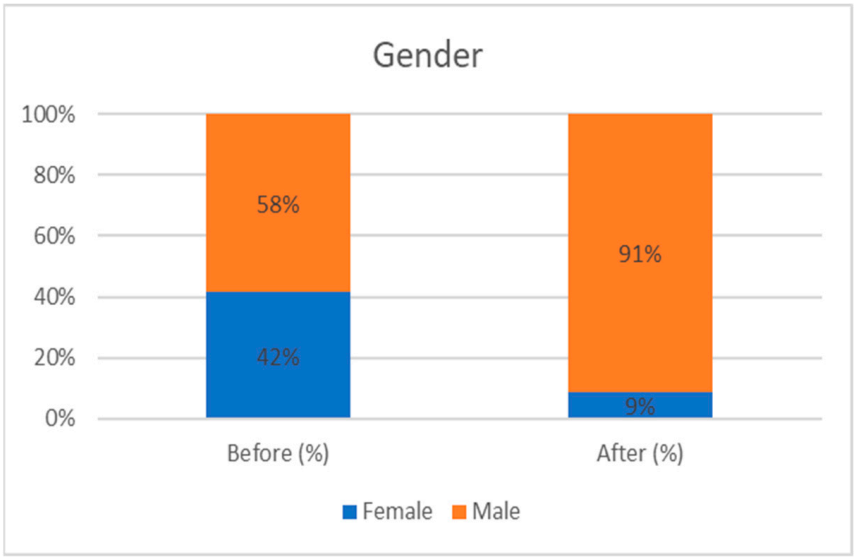

Figure 2. The frequency distribution of gender for respondents in the pre-COVID-19 and post-COVID-19 surveys.

4.1. Comparison of the Results of the Pre-COVID-19 and Post-COVID-19 Surveys

4.1.1. Behavior

The results of the pre-COVID-19 and post-COVID-19 survey analysis showed no significant changes in the behaviors of participants related to RE generation using their HKE. However, there was an increase in the number of participants who believed that their gym activities resulted in wasted energy that could be utilized for renewable energy generation (see Figure 3). The lower rate of "I do not care" responses could be tentatively connected to COVID-related experiences, as was discussed in the literature review.

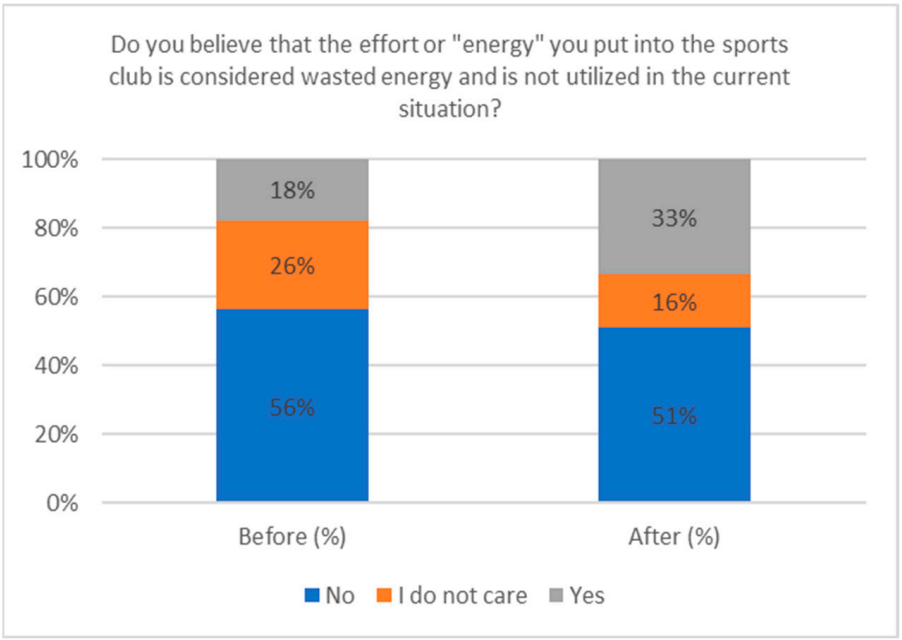

Figure 3. The behaviors of the participants related to HKE harvesting and RE generation before and after COVID-19.

4.1.2. Awareness

The attitudes of participants towards the RE generation via HKE showed little variation. The majority of participants had a positive attitude toward the idea of utilizing HKE

(as shown in Figure 4) for the production of renewable energy. However, there was a slight decrease in the number of participants who had objections to their kinetic energy being used for the production of renewable energy post-COVID-19. Furthermore, there were no significant changes in the preferences and views of the participants regarding renewable energy before and after COVID-19. As evidenced by Figures 5 and 6, the participants' preferences and views on renewable energy in daily life do not reflect any meaningful dynamics. While the preference for renewable energy in daily life remains a priority for nearly three-quarters of respondents, minor fluctuations can be seen in regard to general views on the problem. This suggests that the pandemic did not have a significant impact on the participants' attitudes toward RE generation via HKE. The results imply that there is a potential for utilizing HKE for the production of RE, and this idea can be further explored in the future.

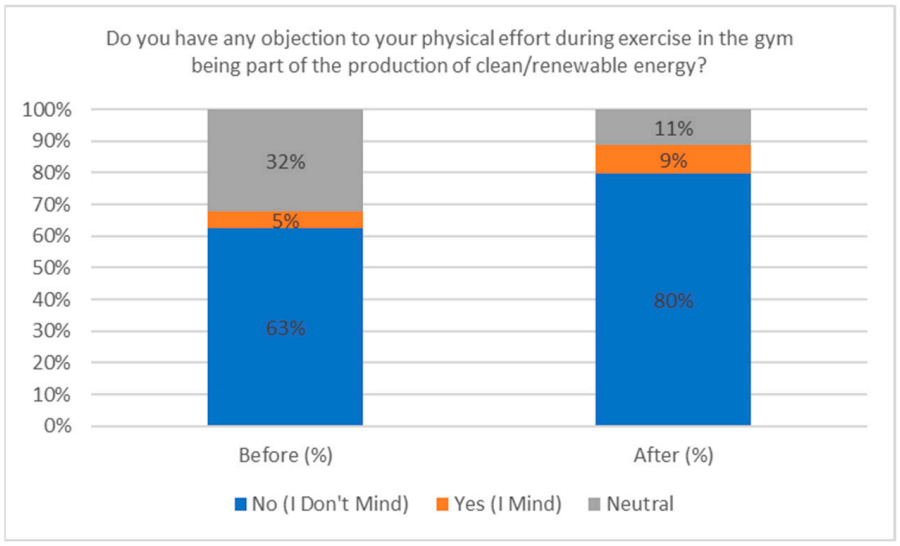

Figure 4. The attitudes of the participants toward HKE generation before and after COVID-19.

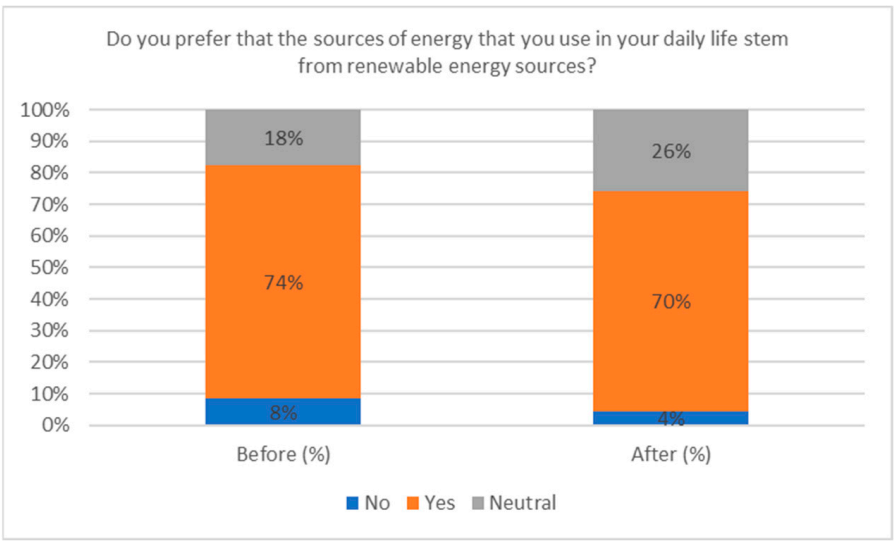

Figure 5. The preferences of the participants regarding renewable energy before and after COVID-19.

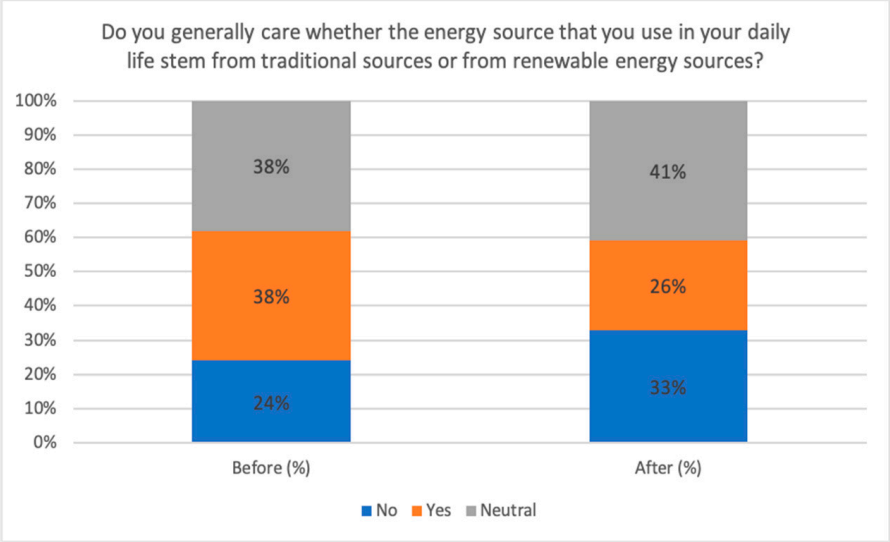

Figure 6. The general views on renewable energy in daily life before and after COVID-19.

4.1.3. Willingness

The results of the two surveys showed that more gym-goers were willing to be morally compensated for their HKE harvesting to generate RE after COVID-19 (see Figure 7). This suggests that COVID-19 has increased awareness and understanding of the potential of HKE as a source of RE generation. Additionally, there was a slight increase in the willingness of participants to be financially compensated for their HKE harvesting in the post-COVID-19 group (see Figure 8). These findings indicate that gym-goers are becoming more open to the idea of utilizing their exercise efforts for the production of renewable energy and are willing to be compensated for their contributions. Overall, the results are encouraging for the promotion and implementation of HKE generation as a source of renewable energy, particularly in the context of sustainable development and Saudi Vision 2030.

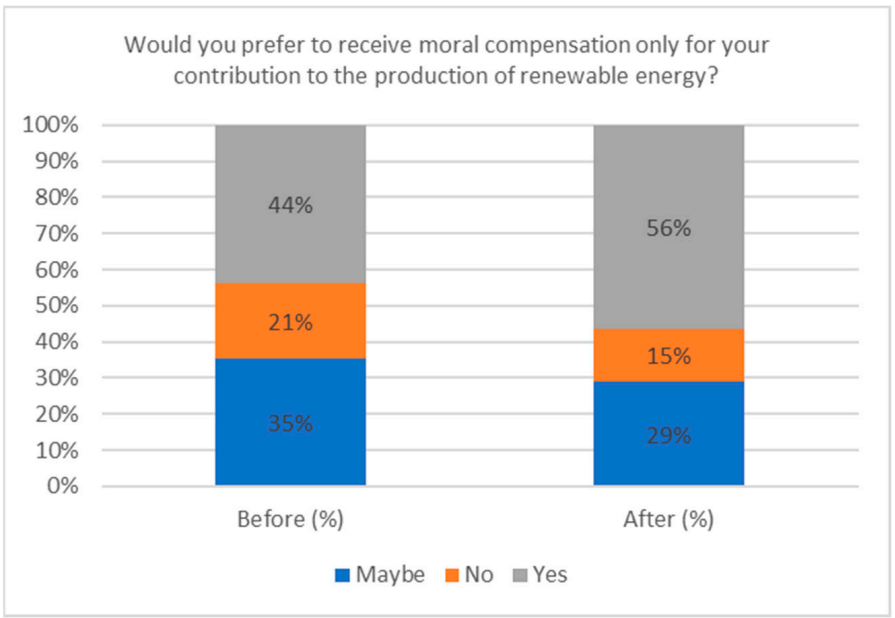

Figure 7. The willingness of the participants to be morally compensated for HKE generation before and after COVID-19.

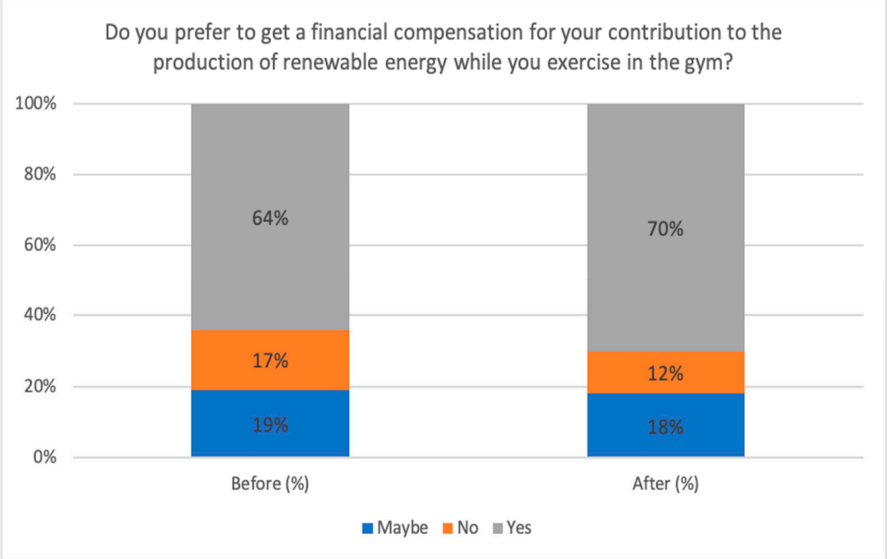

Figure 8. The willingness of the participants to be financially compensated for HKE generation before and after COVID-19.

In conclusion, the comparison of the results of the pre-COVID-19 and post-COVID-19 surveys revealed no significant differences between the attitudes and behaviors of the participants related to the generation of RE via HKE harvesting before and after COVID-19. The main dynamic was due to a higher portion of participants showing a willingness to be morally compensated for their involvement in the HKE generation. Overall, the frequency distributions and mode of the responses to the survey questions were similar between the pre-COVID-19 and post-COVID-19 surveys. Although occasional variations and differences were noted in the demographics and other sections, they cannot be considered significant for the purposes of the chosen research question and hypotheses.

4.2. Statistical Analysis of the Data and Testing of the Hypotheses

To test the hypotheses, statistical analysis was conducted on the data collected from the pre-COVID-19 and post-COVID-19 surveys. The null hypothesis (H0) stated that there is no significant impact of COVID-19 on the gym-goers' willingness to participate in renewable energy generation using their HKE. In contrast, the alternative hypothesis (H1) stated that there is a significant impact of COVID-19 on the gym-goers' willingness to participate in renewable energy generation using their HKE. The Chi-square test of independence was applied to determine the association between the responses of the pre-COVID-19 and post-COVID-19 surveys to the questions on attitudes and willingness towards renewable energy in general and HKE generation, in particular. The results of the Chi-square test did not reveal any significant association between the attitude-focused responses of the two surveys, indicating that there were no changes in the attitudes of the participants related to renewable energy before and after COVID-19.

On the other hand, the Chi-square test revealed a significant association between the awareness-focused responses for one question, indicating that the considerably lower rate of objections could be partially explained by COVID-19-related experiences of the participants (see Table 1). Therefore, the null hypothesis (H0) that there is no significant impact of COVID-19 on the gym-goers' willingness to participate in renewable energy generation using their HKE was not fully rejected. The results do not provide enough evidence to support the alternative hypothesis (H1) that there is a significant impact of COVID-19 on the gym-goers' willingness to participate in renewable energy generation using their HKE.

Table 1. Pearson Chi-square test of independence for the three awareness-focused questions.

	Do You Have Any Objection to Your Physical Effort during Exercise in the Gym Being Part of the Production of Clean/Renewable Energy?	Do You Prefer That the Sources of Energy That You Use in Your Daily Life Stem from Renewable Energy Sources?	Do You Generally Care Whether the Energy Sources That You Use in Your Daily Life Stem from Traditional Sources or from Renewable Energy Sources?
Pearson Chi-square value	26.54	4.5	5.03
Significance ($p < 0.05$)	0.000001	0.1	0.08
Degrees of freedom	2	2	2

5. Discussion

The results of this study indicate that there were no significant changes in the attitudes, behaviors, and willingness of gym-goers related to renewable energy and HKE generation before and after COVID-19. This finding is somewhat unexpected, given that the literature review suggested that COVID-19 had a significant impact on consumer behaviors and attitudes toward renewable energy in general. However, it is important to note that HKE, as a relatively new solution with limited applications, may influence attitudes and behaviors differently compared to other renewable energy sources. The literature review also highlighted the importance of renewable energy in achieving sustainable development goals and the potential of HKE to contribute to this effort [34]. The results of the research support the idea that HKE has the potential to contribute to sustainable development, as the majority of the participants in this study expressed positive awareness and willingness towards utilizing HKE for renewable energy generation. Moreover, the literature review highlighted the connection between the adoption of renewable energy sources and the objectives of Saudi Vision 2030 [37]. The findings of the study support Saudi Arabia's strategic goal of enhancing the nation's reliance on renewable energy sources, as outlined in the Vision 2030 plan. The majority of the participants in this study are Saudi citizens, and they expressed positive awareness and willingness towards utilizing HKE for renewable energy generation, which can be considered a step towards achieving the goals of Saudi Vision 2030.

Possible reasons for the lack of significant changes in the behaviors of the gym-goers before and after the pandemic could be attributed to several factors. One of the main factors relates to the limited availability and accessibility of HKE technology in gyms, which could have hindered participants' ability to engage in renewable energy generation through exercise. Another factor could be the lack of awareness and education about HKE and its potential for renewable energy generation. As mentioned in the literature review, previous studies have reported low levels of awareness and knowledge among consumers regarding renewable energy, which could have influenced their attitudes and behaviors toward HKE generation. Additionally, the reduced capacity of gyms during the pandemic may have limited the potential for HKE generation, which could have contributed to the lack of significant changes in participants' attitudes and behaviors towards renewable energy and HKE generation. These factors may have played a role in the lack of significant changes observed in the study and highlight the importance of increasing awareness and education about renewable energy and HKE, as well as the need for the availability and accessibility of HKE technology in gyms.

To address the concern about the awareness of gym-goers towards HKE for renewable energy generation, it is important to note that the survey questionnaire used in this study included questions to assess the participants' awareness and understanding of HKE and its potential for renewable energy generation. Specifically, the survey included questions about the participants' knowledge of the concept of HKE, their understanding of how it can be used for renewable energy generation, and their level of interest in using their own kinetic energy to generate electricity. These questions were included to ensure that the results of the study were not biased by a lack of awareness or understanding of HKE. The findings

showed that the majority of participants had a positive attitude toward the idea of utilizing HKE for the production of renewable energy, indicating that they were aware of the concept and its potential. Moreover, participants demonstrated a good understanding of how HKE can be used for renewable energy generation, as well as a willingness to participate in the process. Therefore, it can be concluded that the study results are not significantly biased by a lack of awareness or understanding of HKE among the participants. Future studies can delve deeper into the knowledge and understanding of HKE among the general population and explore ways to increase awareness and understanding of this potential energy source.

Moreover, the exploration of HKE as a potential renewable energy source, as well as the understanding of the public attitude towards it, is likely to have broader implications for sustainability research. As demonstrated by previous studies, consumer attitudes and behaviors are closely connected to the expected success of renewable policies and initiatives [45]. By studying these attitudes and determining what impacts them, scholars and policymakers will be better equipped to develop effective strategies for promoting sustainable solutions. Although the necessary technology is yet to be perfected, the implementation of HKE generation systems can become a practical demonstration of renewable energy generation for the general public [46]. In addition to our research, previous studies indicated that wearable and stationary HKE technologies tend to stimulate discussion about sustainability while making observers more enthusiastic about renewable energy use [3,47]. While the overall energy capacity of such solutions is not comparable to conventional methods of renewable energy generation, the former can promote energy efficiency indirectly by providing yet another alternative to fossil fuels [48]. At the time of this research, the topic of HKE generation remains underexplored in regard to its technological, social, and sustainability aspects. Nevertheless, the investigation of public perceptions regarding individual contributions, however small they may be, towards attaining sustainability goals can be consequential for sustainability studies.

5.1. Limitations of the Study and Potential Opportunities for Future Research

The current research has several limitations that should be acknowledged. First, the sample size of the post-COVID-19 survey is larger than that of the pre-COVID-19 survey. This might have affected the generalizability of the results and could be a source of bias. Second, the survey was conducted only in Saudi Arabia, which limits the generalizability of the results to other regions. Therefore, future studies should consider increasing the sample size and conducting surveys in multiple regions to increase the generalizability of the results. Since the article only focused on the attitudes, behaviors, and willingness of gym-goers towards renewable energy and HKE generation, future studies should also consider the feasibility and cost-effectiveness of implementing HKE generation systems in gyms. Furthermore, the authors did not take into account the different types of renewable energy sources and their specific potential for HKE generation, which means that future research should consider this point of concern. In regard to the overall energy balance, the study did not fully address the potential sustainability impact of HKE when compared to other renewable energy generation approaches. As a result, future studies are recommended to quantify potential energy contributions of HKE to better asses its role within the sustainability discourse.

5.2. Implications for SDG and Renewable Energy Policy in Saudi Arabia

The current research has several implications for sustainable development and renewable energy policy in Saudi Arabia. As the findings indicate that COVID-19 has not had a significant impact on consumer attitudes and behaviors towards renewable energy and HKE generation, the efforts to increase the share of renewable energy should continue despite the challenges posed by COVID-19. Considering that findings showcase a comparatively high level of awareness and willingness among gym-goers towards renewable energy and HKE generation, this suggests that there is a potential market for HKE generation systems in gyms. In turn, new renewable energy policies should focus on promoting and

implementing HKE generation systems in gyms as a means of increasing the share of renewable energy in the overall energy mix, a practice that aligns with the goals of Saudi Vision 2030. To capitalize on this potential and foster the integration of sustainability in all aspects of life, new renewable energy policies are recommended to prioritize the promotion and implementation of HKE generation systems in gyms across Saudi Arabia. Additionally, there is a need for comprehensive education and awareness-raising campaigns targeting gym-goers and the general population to highlight the benefits of renewable energy and HKE generation. These campaigns, coupled with financial incentives, such as subsidies or tax credits, as well as technical support and assistance, can further stimulate the development of the HKE sector and facilitate the transition to a more sustainable energy landscape.

The findings of the study also demonstrate the potential advantages of relying on human kinetic energy generation as a renewable energy source for multiple Sustainable Development Goals. Namely, the aforementioned initiatives align with the principles of responsible consumption and production (SDG12) and affordable and clean energy (SDG7), contributing to the sustainable development goals of Saudi Arabia and advancing the country's commitment to a greener and more sustainable future. While HKE might not be feasible as a direct replacement for conventional renewable energy sources, the popularization of sustainability among the population is a crucial for promoting alternatives to fossil fuels. A better understanding of public perceptions on sustainability in response to global events such as COVID-19 is important for implementing future policies driven by SDGs. From another standpoint, the integration of HKE in environments typically reserved for recreation and sports helps to address SDG3 on good health and well-being by coupling environmental sustainability with physical activity. Offering an opportunity to reduce dependence on fossil fuels ever so slightly, the promotion of HKE generation can additionally help to advance SDG13 on climate action.

6. Conclusions

The main objective of this study was to investigate the impact of COVID-19 on Saudi gym-goers' willingness to participate in renewable energy generation using their HKE. The research employed a comparative analytical approach, using two surveys collected before and after the COVID-19 pandemic. Considering that H0 was not fully rejected, it can be concluded that the COVID-19 pandemic had no significant impact on gym-goers' willingness to participate in renewable energy generation using their human kinetic energy. A significant association of responses in the awareness section of the questionnaire proves a degree of association, indicating that a higher number of participants would not object to partaking in HKE generation programs. The authors uncovered a range of consequential implications for the promotion and implementation of renewable energy policies in Saudi Arabia. While the direct impact of HKE is limited, these implications can be critically important for promoting sustainable development in the country, particularly in terms of raising awareness and fostering positive attitudes towards renewable energy and sustainability. Furthermore, the findings have several key implications for renewable energy policy in Saudi Arabia while also aligning with the United Nations' Sustainable Development Goals. By encouraging the integration of HKE generation systems in gyms, Saudi Arabia can make significant progress towards SDG7 on affordable and clean energy and SDG12 on responsible consumption and production. The highlighted connection with SDG 3 and SDG 13 signifies the endeavor's potential to promote a healthy lifestyle while helping to reduce greenhouse gas emissions.

It is crucial to note that, while the immediate impact of HKE on the overall energy production may be limited, its potential closely relates to the broader sustainability implications. The study of public attitudes towards HKE can inform the development and implementation of renewable energy policies and initiatives. The research adds a unique perspective to the field by exploring the potential of HKE as a source of renewable energy in the context of gym-goers' attitudes and behaviors, particularly in the context of the

COVID-19 pandemic. This novel approach introduces valuable insights that can guide the development of strategies to promote the adoption of HKE-based renewable energy generation in the post-pandemic world.

Future research can build upon these findings to explore the potential market for HKE generation systems in gyms, considering recommendations for incentives to drive the implementation of renewable energy systems. The potential for the HKE generation to contribute to the achievement of sustainable development and Saudi Vision 2030 is often overlooked in academia and requires additional research. In this context, future articles focusing on the investigation of a potential market for HKE generation systems in gyms can account for recommendations related to education efforts, awareness-raising campaigns, and HKE-specific incentives to support the implementation of renewable energy systems. As a result, the current paper could serve as a stepping stone towards achieving a more sustainable future for Saudi Arabia.

Author Contributions: Conceptualization, M.F.F. and N.Y.; methodology, N.Y.; software, N.Y.; validation, N.Y. and M.F.F.; formal analysis, N.Y. and M.F.F.; investigation, M.F.F. and N.Y.; resources, M.F.F.; data curation, N.Y.; writing—original draft preparation, N.Y.; writing—review and editing, N.Y. and M.F.F.; visualization, M.F.F.; supervision, M.F.F. and N.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data are available upon request.

Acknowledgments: The authors are grateful to anonymous editors and reviewers for providing valuable insights on the discussed topics.

Conflicts of Interest: The authors declare no conflict of interest.

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