Engineering ergonomic risk assessment of karate choku zuki straight punch

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ABSTRACT

This study utilizes the Rapid Upper Limb Assessment (RULA) technique to evaluate suggested improvements aimed at enhancing the safety and efficacy of the Choku Zuki (Straight Punch), a high-risk karate exercise. The primary objective is to identify and address potential musculoskeletal issues associated with this technique. Given the prevalence of musculoskeletal injuries in sports, particularly in activities with high intensity like karate, the need for reliable ergonomic risk assessment tools such as RULA is paramount. By applying RULA to analyze the ergonomic aspects of the Choku Zuki punch, this study provides crucial insights into potential areas of concern. It identifies specific postures and movements that may predispose practitioners to injury, allowing for the development of targeted interventions to mitigate risks and enhance safety. Furthermore, this research underscores the importance of integrating ergonomic considerations into sports training regimens to optimize performance and minimize injury risks. Beyond its implications for karate training, the study emphasizes the broader significance of ergonomic assessments in sports science and engineering. It showcases how engineering methodologies can be leveraged to improve the safety, efficiency, and overall performance of sporting activities, fostering collaboration between sports scientists, engineers, athletes, coaches, and healthcare professionals to advance sports performance and safety standards.lities.

1. Introduction

Karate is a Japanese martial art that emphasizes ground fighting and hitting. Although it has its roots in Okinawa, Japan, it has since moved over the globe to become one of the most practised martial arts today. Physical methods like strikes, kicks, and blocks are a big part of karate training, but so are mental and spiritual activities like meditation and focus training (Moore et al., 2020). Karate has been proven to have positive effects on a person's body, mind, and spirit. The National Institutes of Health (NIH) in the United States conducted a literature analysis and found that karate was associated with gains in fitness, flexibility, balance, and self-defence (Moore et al., 2020). Regular karate training has also been shown to have positive effects on mental health, including decreased stress, anxiety, and sadness and greater emotions of self-worth (Sheu et al., 2015; Von Mackensen, 2007). Cognitive abilities including attention, working memory, and processing speed have all been proven to increase during karate training (Dwojaczny et al., 2021). These results highlight the value of karate as an activity that improves both physical and mental health.

The risk of injury, the expense of training and equipment, and the time commitment necessary to participate in the sport are just some of the most common drawbacks of karate (Thibaut et al., 2017). Despite the many physical and mental benefits, karate does have its drawbacks. Due to the rigorous nature of karate training, trainees may also endure mental and physical exhaustion, as well as elevated levels of stress. Because of the high-impact nature of the moves used in karate, injuries are common. Karate trainees are vulnerable to a wide range of injuries, including muscle tears, bone breaks, flesh wounds, and even internal bleeding. Knee injuries, hand and wrist injuries, and ankle sprains are among the most typical outcomes of karate training. Because of the repeated nature of some karate techniques, overuse problems are also a possibility (Abdul Latif et al., 2022). Karate practitioners frequently experience musculoskeletal disorders (MSDs) due to factors such as weak muscles, poor form, compensatory strategies, and overuse of joints and muscles (Mastnak, 2017). The back, shoulders, neck, and upper limbs are only some of the areas that can be affected by these illnesses (Davies & Davies, 2013). This can lead to a wide range of symptoms, from mild discomfort to serious illness. Karate trainees should be aware of the risks involved and take precautions to avoid MSDs as they train (Emad et al., 2020).

Protection from injuries is a significant problem in sports medicine (Pal, 2020). The necessity to understand the influence of karate practice on the health of players and avoid or mitigate any bad effects from certain motions has been underlined in various studies (Violan et al., 1997; Zhu, 2022). Some of the methods for investigating MSDs in karate include: Physical examination: A physical examination by a sports medicine physician or physiotherapist can assess the athlete's posture, range of motion, and muscle strength, and identify any visible signs of MSDs such as swelling or tenderness. Functional movement screening: Functional movement screening (FMS) is a system that assesses an athlete's movement patterns and identifies any limitations or asymmetries that may contribute to MSDs. FMS can help develop personalized exercise programs to address any identified issues and reduce the risk of MSDs. Imaging tests: Imaging tests such as X-rays, MRI, or CT scans can help identify any structural abnormalities or damage that may be contributing to MSDs in karate athletes.

Electromyography (EMG): EMG can be used to assess muscle activity and identify any imbalances or weaknesses that may be contributing to MSDs. Biomechanical analysis: Biomechanical analysis uses motion capture and force measurement systems to assess an athlete's movements during karate techniques and identify any biomechanical factors that may be contributing to MSDs. Patient questionnaires: Patient-reported outcome measures (PROMs) can help assess how karate athletes perceive and experience their MSDs, and identify any factors that may be contributing to their condition. Despite the efficacy of the mentioned approaches, it is possible that MSDs in Karate athletes may remain unidentified and that no definitive remedies will be found for the underlying issues. Therefore, it is crucial to create novel methods for assessing these issues and locating preventative measures. The Rapid Upper Limb Assessment (RULA) is a promising method since it can evaluate the ergonomics of job tasks and spot potential causes of MSDs. Karate is one activity where RULA has been developed for usage in order to evaluate the ergonomic risks associated with specific moves and determine how they might be mitigated by practice or training changes. It is possible that MSDs can be better understood, and effective therapies that minimize injury risk and enhance long-term outcomes for athletes, could be created, if researchers took a multidisciplinary approach that combined diverse approaches and tools, such as RULA. Research and development in this area should be continued to ensure that karate athletes can engage in the sport without risk to their health and performance. The RULA has been widely employed in prior research studies to quantify musculoskeletal strain in different sports (Hadi et al., 2022; Dabholkar & Dudekula, 2019; Barragan al., 2022). The choku-zuki punch (Straight Punch) from karate training (shown in Figure 1) will be the focus of this study, and the RULA will be used to examine the incidence of MSDs and pinpoint their causes. Upper limb posture and applied forces will be evaluated using RULA to determine any ergonomic risks related to the procedure. Potential causes of MSDs can be determined by studying the RULA assessment results, and then ideas for adjusting training practices can be made to get rid of or lessen these dangers. It is possible to improve the health and safety of karate athletes by recognizing and addressing the causes of MSDs.

Figure 1. Illustrative picture of the final moment of choku-zuki punch (Straight Punch)

2. Literature review

2.1 Karate and injuries

Karate injuries are well-studied because of their frequency and severity. Bruises, sprains, and strains are the most commonly reported injuries (Critchley et al., 1999), however, incidence rates vary from study to study. Most karate injuries occur in the lower extremities, followed by the head and neck (Zetaruk et al., 2005). Younger and less seasoned trainees were also more likely to have injuries during training. There were also reports of similar results (Destombe et al., 2006; Sterkowicz & Sterkowicz-Przybycień, 2013). They also found that the most common method of injury was via kicks. A systematic review found that ankle injuries were the most common type of lower extremity injury among karate practitioners (Thomas & Ornstein, 2018). They also talked about how serious the injuries were, saying that fractures and dislocations were the worst. Potential risk factors for injuries were age, sex, and skill level (Murphy et al., 2003; Zetaruk et al., 2000). Warming up, stretching, perfecting form, using protective gear, and altering competition rules were all highlighted as crucial steps in reducing the likelihood of injury (Steffen et al., 2010). Problems with conditioning and lack of rest were singled out as causes for concern that must be addressed. After regulation adjustments were implemented, both the number of injuries and their severity were said to have decreased (Arriaza et al., 2009).

2.2 Rapid Upper Limb Assessment (RULA)

In order to identify and assess the severity of potential MSDs associated with upper limb duties, RULA is a popular tool for conducting Engineering Ergonomic Risk Assessment. The RULA approach was created by McAtamney and Corlett (1993) to evaluate the ergonomic risks associated with upper limb postures and movements across different sectors of the economy. The evaluation of worker postures and movements across multiple industries led to the creation of the flowchart-based tool shown in Figure 2, which provides a systematic and effective method for identifying ergonomic risks associated with upper limb postures and motions. The authors present case examples illustrating the application of RULA to the evaluation of upper limb diseases resulting from employment in a range of settings, from manufacturing to office work. The findings from these case studies show that RULA is capable of recognizing ergonomic risks and providing actionable recommendations for mitigating them. In their review of the RULA method and its applications, McAtamney and Corlett (2004) underline the benefits of the RULA approach above other ergonomic evaluation techniques. Workstation changes and ergonomic training were found to be effective in reducing RULA-measured ergonomic risks associated with sitting at a desk all day (Widiyawati et al., 2020). Moreover, RULA was used to assess ergonomic risks among healthcare professionals discovered that interventions such as ergonomic training, workplace changes, and the use of assistive equipment can help to prevent MSDs in this population (Kakaraparthi et al., 2022).

Figure 2 RULA Worksheet (Ergo Plus, 2024)

2.3 Rapid Upper Limb Assessment (RULA) and sports

Some studies have investigated the ergonomic dangers associated with certain sports activities, like baseball throwing or golf swinging, and offered adjustments to lessen these risks (Hadi et al., 2022; Dabholkar et al., 2019; Barragan et al., 2022), but research on the implementation of the RULA technique in sports settings is limited. In sports, however, the RULA approach is not consistently used. However, the RULA approach may be modified to evaluate ergonomic concerns in sports. Although the RULA was designed for use in analyzing ergonomic risks in the workplace, it may be tested in a sporting context. The design of equipment, the methods of training, and the repetition of certain movements are all potential sources of ergonomic risk in sports. The RULA technique has the potential to be used for this purpose by analyzing the athletes' posture and motions while they are training or competing to spot regions of high ergonomic risk. Based on the results of the assessment, improvements could be made to training methodologies, equipment design, or other factors to lessen the risk of injury or strain. Overall, more investigation and research are needed to determine the relevance and efficacy of the RULA approach in sports situations.

3. Materials and methods

3.1 Methods of investigation

The purpose of this research was to examine whether or not the karate technique known as Choku Zuki (Straight Punch) is useful in lowering the risk of injury and mental strain for practitioners. There were four steps used to accomplish this goal. To begin, the RULA method was applied to the karate choku-zuki punch. The punch was evaluated by professional karate practitioners to identify potential injury risks. In the second step, proposed adjustments targeted at decreasing injury and stress during training were produced based on the results acquired from step one. Step three involved creating a control group and an experiment group. Based on the findings from step one, the experimental group was given the suggested adjustments to their training regimen in an effort to reduce the incidence of injury and stress. In contrast, those in the control group kept up with their usual workouts. The karate choku-zuki punch was modified to reduce the potential for serious injury. In the fourth step, Patient-reported outcomes (PREs) questionnaires were used to assess injury and stress during karate training for both groups. Injuries and stress related to karate training were assessed with the help of questionnaires. Finally, the two sets of step three data were compared to see how well the recommended changes mitigated damage and stress during karate training. Statistical methods were applied to the data in order to see if there were any discernible changes between the control and experimental groups. Figure 3 depicts the procedure flowchart. Based on the general approach in Figure 3 to assess the ergonomic risk of the karate choku-zuki punch depicted in Figure 1, RULA scores will be calculated for each participant following the RULA posture guide (Figure 2). We will evaluate postures for neck, trunk, upper arm, lower arm, wrist, and hand position during the punch movement. Additionally, we will consider the force exerted, twist of the wrist, and coupling. Scores will be assigned based on the RULA scoring chart for each category, and then summed to generate a cumulative RULA score for each participant. This approach provides a quantitative assessment of the musculoskeletal risk associated with performing the karate choku-zuki punch. Overall, this approach enabled a thorough analysis of the performance improvement method's potential to lessen the occurrence of injury and mental strain during karate practice. Evidence-based insights into efficient injury prevention and stress reduction measures for karate practitioners and instructors can be gained from this study.

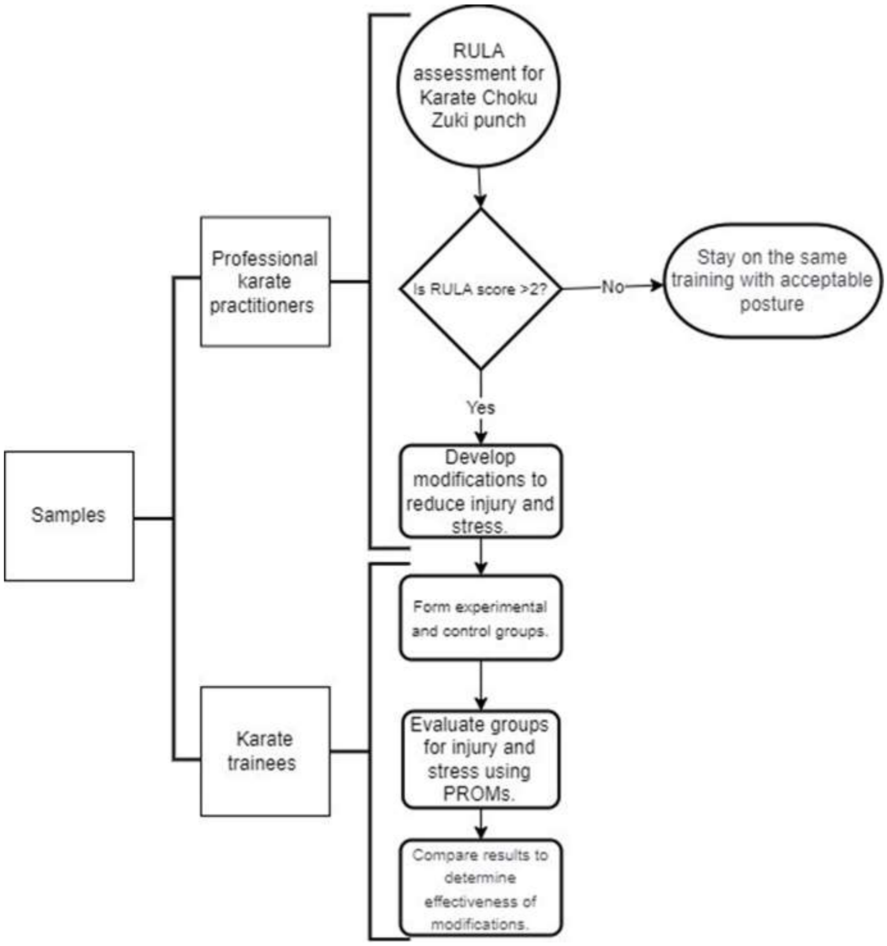

Figure 3 Flowchart illustrating the RULA-based method for investigating the effectiveness of a performance improvement approach in reducing injury and stress during karate training

3.2 Participants

The initial part of the study's methodology involved selecting a group of highly experienced professional karate practitioners to provide feedback on the RULA technique's assessment of the karate choku-zuki punch. The 30 participants were split into three groups of 10, and all had at least two years of karate experience and knowledge of the choku-zuki punch before being recruited. The evaluation was conducted with the highest precision and competence because of the involvement of highly experienced practitioners. The practitioners were split into three groups to guarantee the validity and consistency of the findings. The analysis took into account the most important findings from each group and settled on an average score. This analysis was conducted to determine the likelihood of experiencing harm from a punch. Karate trainees aged 18 to 40 were eligible for steps 3 and 4, as were those with a body mass index (BMI) of 18.5 to 24.9 and a total body weight of less than 113 kilograms (250 pounds). People who have MSDs or injuries that could impact their movement or posture were not included. Despite efforts to recruit a representative sample, results may not apply to people who fall outside the study's parameters for age, BMI, medically-explained differences, or injuries. An effect size, statistical power, and significance level suited to the study design were used to determine that a total of 60 participants (30 in each group) would be sufficient for meaningful results. The RULA method (an evaluation of upper limb postures during training) and self-reported surveys (collecting information on injuries and stress levels during training) were used to evaluate the efficacy of the performance improvement method. Before any data were collected, the study methodology was reviewed and approved by the Mutah University IRB. Before enrolling in the trial, all participants were given information regarding the study's goals, methods, and any potential risks or benefits. Volunteers were reassured that they could stop taking part in the study at any time without any negative consequences. To protect the privacy of the participants, all data were encrypted and kept secret.

4. Results and discussion

4.1 RULA score calculation for karate Choku-zuki punch

The results of the initial step of evaluating the choku-zuki karate punch using the RULA method are shown here. Experts in the art of karate were called in to assess the punch and determine its potential for harm. One participant's punch is seen in Figure 1; the results were recorded by the same team of professional karate using the fuzzy logic method developed by Albzeirat et al. (2022). A RULA score was created for each side of the body using the RULA method depicted in Figure 2, with the scores for each RULA step based on the average values of the professional karate practitioners. Table 1 displays the assessment's findings.

Table 1 RULA Scoring Table for Choku-zuki Karate Punch.

RULA Step Number	RULA Step Name	Right Side Position	Right Side Score	Standard Deviation	Left Side Position	Left Side Score	Standard Deviation
1	Locate Upper Arm Position	Upper arm angle: 20 in extension	+2	0.69	Upper arm angle: +90	+4	0.44
2	Locate Lower Arm Position	Lower arm angle: 60-100	+1	0.43	Lower arm angle: 0-60	+2	0.46
3	Locate Wrist Position	Wrist angle: 0	+1	0.51	Wrist angle: 0	+1	0.62
4	Wrist Twist	The wrist is twisted in mid-range	+1	0.23	The wrist is twisted in mid-range	+1	0.17
5	Look-Up Posture Score	Posture score based on upper arm lower arm angles, wrist position and wrist twist values from steps 1-4	+2	0.74	Posture score based on upper arm lower arm angles, wrist position and wrist twist values from steps 1-4	+4	0.55
6	Add Muscle Use Score	Action is repeated occurs 4X	+1	0.12	Action is repeated occurs 4X	+1	0.07

		per minute			per minute		
7	Add Force/Load Score	Load is less than 4.4 lbs	+0	0.27	Load is less than 4.4 lbs	+0	0.10
8	Find row in Table C	Add values from steps 5-7	+3	0.19	Add values from steps 5-7	+5	0.42
9	Locate Neck Position	Neck posture angle: 10-20	+2	0.15	Neck posture angle: 10-20	+2	0.13
10	Locate Trunk Position	Trunk posture angle: 0-20	+2	0.57	Trunk posture angle: 0-20	+2	0.40
11	Legs	Legs and feet are supported	+1	0.33	Legs and feet are supported	+1	0.29
12	Look-Up Posture Score in Table B	Posture score found from Table B from steps 9-11	+2	0.49	Posture score found from Table B from steps 9-11	+2	0.22
13	Add Muscle use Score	Action is repeated occurs 4X per minute	+1	0.61	Action is repeated occurs 4X per minute	+1	0.36
14	Add Force/Load Score	Load is less than 4.4 lbs	+0	0.09	Load is less than 4.4 lbs	+0	0.18
15	Find Column in Table C	Add values from steps 12-14	+3	0.23	Add values from steps 12-14	+3	0.38
Scoring	Final score from Table C	Values from steps 8 and 15	+3	0.41	Values from steps 8 and 15	+4	0.19

For the right side, the upper arm angle was +20 degrees in extension and scored +2, while for the left side, the position was +90 and scored +4. The lower arm angle for the right side was between 60-100 and scored +1, while for the left side it was between 0-60 and scored +2. The wrist position for both sides scored +1, and the wrist sprain in the midrange scored +1 for both sides. The position score for the right side was +2, and for the left side, it was +4. The muscle use score for both sides was +1, and the strength/load score was +0 for both sides. By totaling the scores from Steps 5 through 7 and referring to Table C (Step 8), we obtained a score of +3 for the right side and +5 for the left side. Steps 9-11 evaluated the neck posture angle for both sides (10-20 scored +2), trunk posture angle for both sides (0-20 scored +2), and support for both legs and feet (scoring +1 for each side). Using Table B from Steps 9-11 to determine the posture score and adding the muscle use and strength/load scores for Steps 12-14, the score for both sides were +3. Finally, adding the scores from Steps 8 and 15 yielded the final RULA score for the right and left sides of +3, +4, respectively, indicating the need for further investigation and potential modifications to mitigate injury risks.

4.2 Proposals for training modifications to reduce injury and stress

First-step data informed a recommendation for change the studied punch's execution. Changing the timing and trajectory of a punch is a difficult task that necessitates retraining the body's muscle memory. It was proposed that changing other factors of training, such as frequency and intensity of repetitions, may be more viable in minimizing injury risk. Therefore, in this study, it was advised to estimate the risk associated with performing the punch by decreasing the repetition of the punch during training while leaving the punch specifications unchanged. Similar to the first step, the risk level was reevaluated using the RULA score, and it was found that the altered punch resulted in an RULA score of 2 on the right side and 3 on the left, successfully achieving the goal of risk minimization.

4.3 Effectiveness of modified karate training proposal in reducing injury and stress

PROMs, or patient-reported outcome measures, were used to evaluate the risk of injury and stress during karate instruction in both the control and experimental groups. Injuries and stress related to karate training were assessed with the help of questionnaires. We compared the two groups to see who had a lower incidence of injury and stress while training in karate after implementing the suggested changes. Statistical method t-test was applied to the data in order to see if there were any discernible changes between the control and experimental groups. While the control group experienced injuries and stress connected to the punch during typical training, the experimental group, which received adjustments aimed at lowering injury and stress, reported no such injuries or stress. The t-test resulted in a p-value of 0.32 where this value >0.05, suggesting no statistically significant difference in performance between the groups, however, limiting repetition could reduce the likelihood of damage during training. In light of these results, it is clear that minimizing repetition and other training factors can help reduce the likelihood of injury or stress during karate practice. These precautions should be incorporated into future karate training sessions to ensure the health and safety of participants.

5. Conclusions

The purpose of this research was to analyze the karate punch known as the choku-zuki using the RULA approach in order to determine its harm potential and recommend changes to mitigate said potential. The RULA approach was shown to be useful in evaluating ergonomic risk factors associated with karate training, and the results indicated that more research and possible changes were needed to reduce injury risks. It was suggested that the training punch be modified in order to decrease repetitions while maintaining the same punch parameters. The modified punch training was successful in lowering the RULA score and thus the associated danger. Modifying training components, like minimizing repetition, can reduce the risk of injury or stress during karate training. The experimental group that received the adjustments aimed at reducing injury and stress reported no injuries or stress during the training time. These precautions should be incorporated into future karate training sessions to ensure the health and safety of participants. This research lays the groundwork for applying the RULA method to the assessment of additional athletic movements in the context of training and competition.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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