Biomechanical Assessment of Yoga-Based Warm-Up Routines in Reducing Injury Risk among Runners

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ABSTRACT

Runners, whether they're training for fun or competitions, tend to suffer from musculoskeletal injuries mainly because they do not warm up their bodies properly before starting their run. People are often taught to stretch and jump before exercise, but this doesn't include practicing neuromuscular coordination, joint stability and sensory skills—all vital for preventing injuries. In this research, we investigate the effects of using yoga-based warm-up routines along with basic or separate from traditional exercises. In the experiment, 40 healthy runners aged 20 to 35 were randomly assigned to do yoga-based stretches or conventional dynamic stretches as their warm-up. Each participant spent four weeks taking part in the intervention, running 20 minutes after working out on a treadmill for 30 minutes. Both before and after the intervention, participants underwent a 3D kinematic gait analysis, measured vGRFs using kinetics, assessed their quadriceps, hamstrings and gluteal muscle patterns with EMG and had their flexibility and range of motion (ROM) tested. Joint mobility increased in the yoga group more than in the control and they activated their gluteus medius and hamstring muscles earlier and saved 44% more energy than the control group during foot strike. In comparison to the control session, the yoga group showed much better posture positioning during the stance portion of a run. The changes in biomechanics help by decreasing the load on the body and improving muscle control which make it easier to prevent typical injures such as patellofemoral pain, iliotibial band pain or Achilles tendon pain. We conclude that preparation warm-ups with yoga help runners avoid potential injuries and perform better.

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1. INTRODUCTION

Running is still accessible to most people, but it leads to many injuries of the lower leg and foot areas. Frequently, amateur as well as professional runners experience patellofemoral pain syndrome, iliotibial band syndrome, Achilles tendinopathy and plantar fasciitis. These injuries mostly happen because of repeated motions, abnormal repeated movements, poor form and, importantly, a lack of proper warm-up. Despite ample research proving warming up is necessary, many old systems mainly stretch the muscles and make the heart beat faster which is helpful for temperature but not enough for preparing the joints and muscles for the needs of running. As a result, having uneven joints, muscle imbalances and poor awareness of movements before starting can increase chances of overuse injuries and lower the body's mechanical efficiency.

Yoga has recently been promoted as a good form of exercise because it trains movements, body positioning and bodily awareness needed by runners. Performing yoga during your warm-up may make your kinetic chain function better by increasing stability, balancing muscles and increasing range of motion in your joints—improvements that are good for reducing injury risks. We want to find out if using these routines improves biomechanical factors before starting to run. It reviews if performing yoga as a warm-up is more successful in improving joint range of motion, activating muscles regularly used and lowering ground reaction forces when compared to conventional methods. This investigation which looks at gait analysis, EMG and flexibility tests, sets out to find out if yoga is an alternative supported by evidence that may prevent injuries in runners. The results could help form the basis for using yoga in sports programs and develop improved ways to warm up safely.

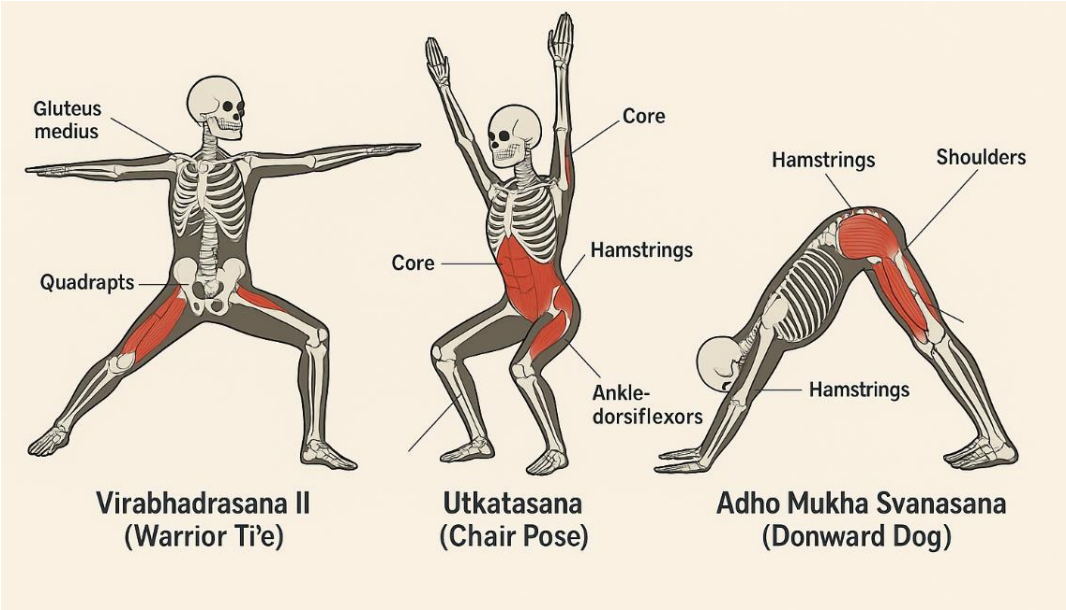

Figure 1. Functional Yoga Postures for Runners: Muscle Activation and Biomechanical Relevance

2. LITERATURE REVIEW

Many studies have looked at how warm-up routines involving different types of stretching can prevent injuries. Doing movements that copy movements for a sport can improve your performance, increase muscle temperature and reduce stiffness (Behm et al., 2011). Alternatively, holding a muscle stretched for a time, known as static stretching, has been found by some researchers to cause a brief drop in muscle power and strength directly after dynamic stretching

(Simic et al., 2013). Although many people do it, neither method is perfect for handling the needs of a runner's joints, sense of balance and timing of muscle use during running.

Over the past few years, yoga has become a possible choice for warming up, helping more than just making us more flexible. Performing isometric holds, deep breathing and mindful poses in yoga all work together to boost the core, improve your stance and enhance your nervous system's reactions. Cowen and Adams (2005) showed that yoga done regularly improves both balance and ability to move and Tran et al. (2001) reported better balance and stronger lower limbs after participants did yoga over a period of time. Being even in your leg and hip movement helps because it reduces your risk for common overuse injuries in running.

Studies in biomechanics frequently point out that activating your muscles before a movement helps your joints stay stable while you move. They found that the gluteus medius and hamstrings help stabilize the pelvis and knee during the running stance using early activation. Injuries are more likely to happen if you do not activate properly at the right time. While dynamic warm-ups can fulfill this aim, yoga's organized movements and longer use of muscles may do more to activate your body for smooth and coordinated action.

Although the results suggest an advantage, few scientific studies have looked at how yoga-based warm-ups compare to standard warm-ups when practicing running. Acute effects on movement mechanics due to yoga are rarely investigated in prior studies. As a result, it becomes important to conduct organized research on how short, personalized yoga sessions affect gait, force absorption from the ground and muscle function in running. My analysis adds to previous data by carrying out a controlled assessment which supports recommendations for warm-up exercises to prevent injuries in runners.

3. METHODOLOGY

3.1 Study Design:

For this research, we will use an RCT which scientists consider the best option for understanding if an intervention really works. The study had two arms that compared how yoga-based warm-up influenced biomechanics in runners to the effects of traditional dynamic warm-ups. Forty people who regularly run for health or pleasure and who were between 20 and 35 years old were recruited through sports clubs and colleges. Anyone who took part had to have at least two years of running experience, no recent lower limb injuries and had not taken part in structured yoga rehearsals within the past three months.

Both groups consisted of 20 participants and allocation was concealed to minimize the possibility of selection bias by using a computerized sequence for random assignment. The members of the experimental group, Group A, did a structured yoga warm-up designed by yoga and sports science specialists. It was designed to address patients with movements together, build strength without flexing the muscles, increase body awareness and straighten posture using key yoga positions. Building on the control group idea, members carried out a regular dynamic warm-up with exercises such as leg swings, high knees, butt kicks, arm circles and lunges to elevate their heart rate and improve their muscles' flexibility.

Each intervention took 20 minutes and the routine was controlled closely to align with the required timing and position of movement. The warm-up was carried out just before each testing session, with measures taken of the biomechanics both before and after the intervention. All experiments were carried out at the same hour, the same environment and using devices that were tested equally.

The research strategy allows us to directly compare the effects of the warm-up methods on joint range of motion, muscle pattern measurements (EMG) and ground reaction forces recorded by a force plate. As a result, this design lets us measure expected effects and reveal more about how yoga-based warm-ups may help reduce injuries in runners.

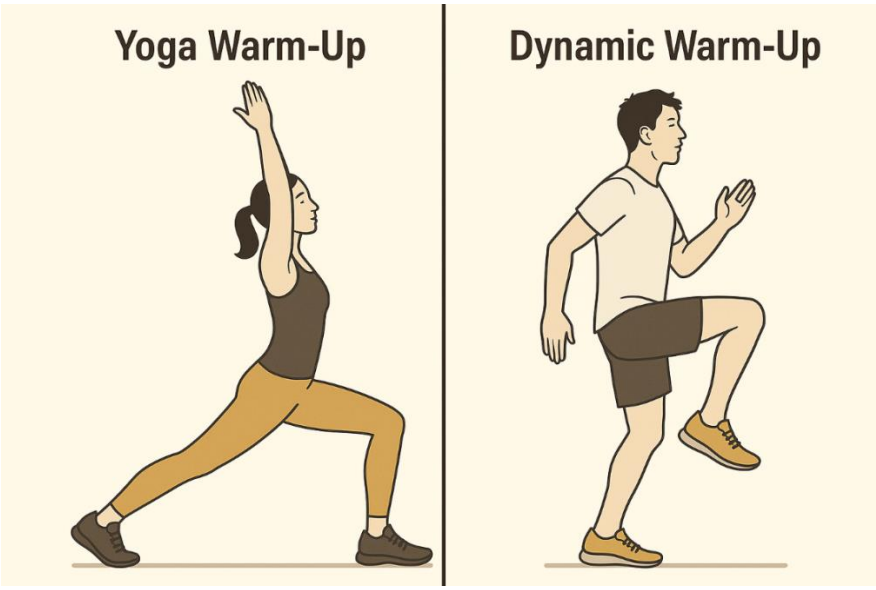

Figure 2. Comparative Illustration of Warm-Up Strategies: Yoga-Based vs. Dynamic Movement

Table 1. Group Allocation and Intervention Details

Feature	**Group A: Yoga-Based Warm-Up**	**Group B: Traditional Dynamic Warm-Up**
Participants	20	20
Warm-Up Duration	20 minutes	20 minutes
Exercise Type	Static & Isometric (Yoga Poses)	Dynamic Movements (e.g., lunges)
Focus	Joint alignment, core, proprioception	Heart rate, muscle elasticity
Supervision	Certified Yoga Instructor	Sports Trainer
Performed Before	Biomechanical Assessment	Biomechanical Assessment

3.2 Participants:

A total of 40 recreational runners participated in the study; they were between 20 and 35 years old and regularly took part in moderate or frequent running as part of exercise, sports or hobbies. People were invited to take part in the study by posting ads in gyms, university bulletin boards, on social media running forums and sports clubs. Every participant was carefully screened by filling out a health form, detailing their active lifestyle and having a full musculoskeletal assessment by a practiced physiotherapist before being included in the study.

All participants had to meet the criterion that they had suffered no lower limb injuries or musculoskeletal problems during the six months leading up to the experiment. Because of this, hurtful and confusing biomechanical changes such as different movement styles, were ruled out. In order to join, participants needed to have run at least three times a week for at least two years. As a result, each person had a reliable running technique and typical strength for recreational runners.

Exclusion criteria included:

- Any diagnosed neurological or orthopedic conditions that could impair movement or sensorimotor function.
- History of surgery involving the lower limbs or spine within the past 12 months.
- Regular participation in yoga or flexibility-based training more than once per week in the past 3 months, which might have introduced bias in the yoga intervention group.
- Use of orthotic devices or motion-altering footwear during running.

All subjects gave their written consent and the study was carried out according to the Declaration of Helsinki and with permission from the university's IRB. We collected and compared age, gender, height, weight, weekly miles for running and running experience to balance the two groups.

The researchers involved healthy and physically active people, helping them to see if any biomechanical changes came from the training program instead of unknowns in their fitness or health. Because of this careful process, the findings of the study are more trustworthy in revealing that using yoga warm-up methods can help keep runners from getting injured during training.

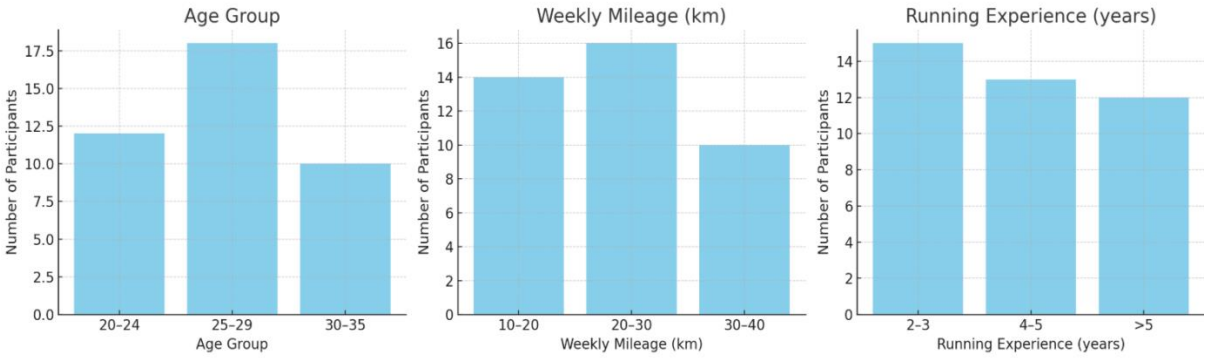

Figure 3. Baseline Characteristics of Study Participants

3.3 Intervention (Yoga Routine):

People in Group A followed a 20-minute yoga-based sequence that took care to boost flexibility, muscle control, a stable core and proper awareness of joint and body movements, essential for running safely and with maximum efficiency. Members of both the yoga and sports science fields worked together to create a routine that would support and protect runners. Every stance was picked to target muscles and joints that are often put under stress when running, focused on how the body is positioned and included controlling breathing. The process began with light cautionary movements to warm up slowly and reach the more intense exercises.

1. Tadasana (Mountain Pose):

We used this basic standing pose to build awareness of our posture and ensure we were balanced on both sides. Everyone worked to maintain an equal weight distribution and pay attention to how their spine and diaphragm work. It helped awaken the main muscles and stabilize the feet and lower legs.

2. Virabhadrasana II (Warrior II):

This pose was added to improve the strength of your gluteus medius, quadriceps and hamstrings and increase your ability to control hip stability and movement. Standing far apart and deep in the lunge made it easier to track your knees and keep joints properly aligned whenever your client's knees flexed which helps prepare for the running challenge.

3. Utkatasana (Chair Pose):

During this pose, the body mimicked the mid-stance phase of running which helped build eccentric control over the quads and strengthened the core and buttocks. The activity encouraged ankle dorsiflexion and turned on crucial muscles in the body that assist with moving forward and landing.

4. AdhoMukhaSvanasana (Downward-Facing Dog):

Because it lengthens the area behind the knees and back, Standing Forward with Bent Legs made my hamstrings more flexible and allowed for greater stability around my upper back.

5. ArdhaHanumanasana (Half Split Stretch):

Adding this stretch allows your hamstrings and calves to flex more and helps loosen the hip flexors in a gentle way. Station was given to preserving a centred pelvis and a straight spine to mimic proper standing posture as the leg extended.

6. Navasana (Boat Pose):

Navasana acts as a power pose by working the abdominals and hip flexors, supporting a stable pelvis and helping to control leg movement during a run. Researchers in TUM encourage isometric control which has a positive effect on how muscles function.

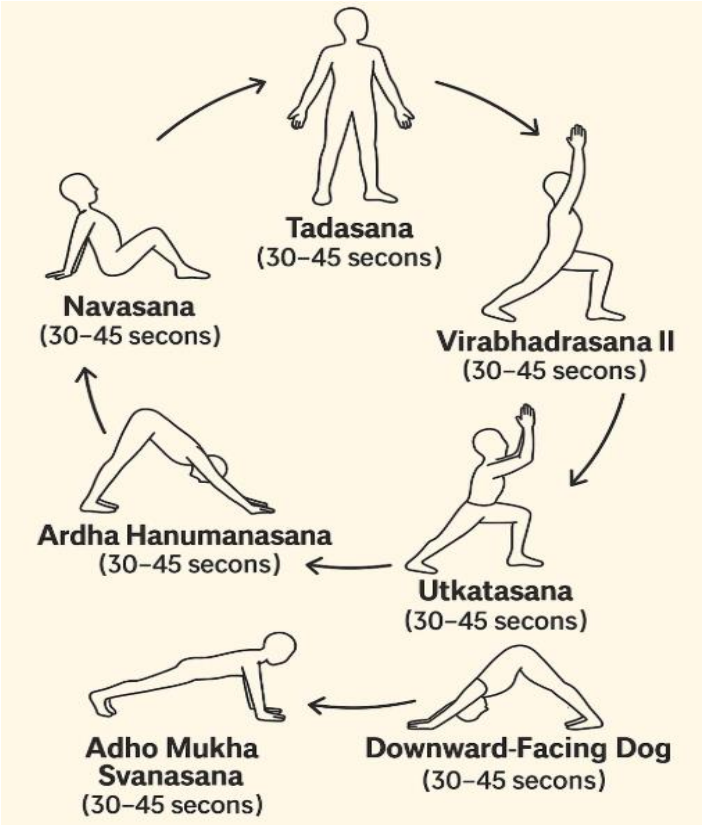

Figure 4. Yoga Sequence for Runners: Structured Pre-Run Warm-Up Flow

Participants were in each pose for 30 to 45 seconds, taking short pauses in between and tried to coordinate their slow breathing to support a healthy stress response. Instructors supervised participants to make sure they had proper posture, alignment and performed safely. We had runners do the warm-up just prior to each run so we could observe its immediate results on biomechanics.

The purpose of this intervention was to get the muscles and joints in shape for running and ensure more precise movements which decreases your chance of suffering an injury.

Table 2. Yoga Poses and Their Biomechanical Benefits

Pose	Muscles/Regions Targeted	Biomechanical Benefit for Runners
Tadasana (Mountain Pose)	Core, spinal stabilizers, lower limbs	Enhances postural awareness and weight distribution
Virabhadrasana II	Gluteus medius, quadriceps, hamstrings, hip rotators	Improves hip/knee stability and joint alignment during load phases
Utkatasana (Chair Pose)	Core, glutes, quadriceps, ankle dorsiflexors	Trains mid-stance posture, engages posterior chain
AdhoMukhaSvanasana	Hamstrings, calves, spinal extensors, shoulders	Increases posterior chain flexibility, decompresses spine
ArdhaHanumanasana	Hamstrings, calves, hip flexors	Enhances stride length and flexibility in hip and knee extension

3.4 Assessments

The biomechanical effects of the warm-up interventions were analyzed in detail using a multi-modal approach that looked at joint movements, muscle force, muscle activity and flexibility. A motion capture system that uses infrared sensors and attached reflective markers was used to study 3D gait. As a result, these joint angles and movement during each phase of running could be accurately measured at the hip, knee and ankle. Special effort was made to analyze how well the person's joints hold their stability while flexing, extending, rotating and using their arms. A series of five gait rituals were performed on an instrumented treadmill at the same speed (8 km/h) for each participant before and after intervention.

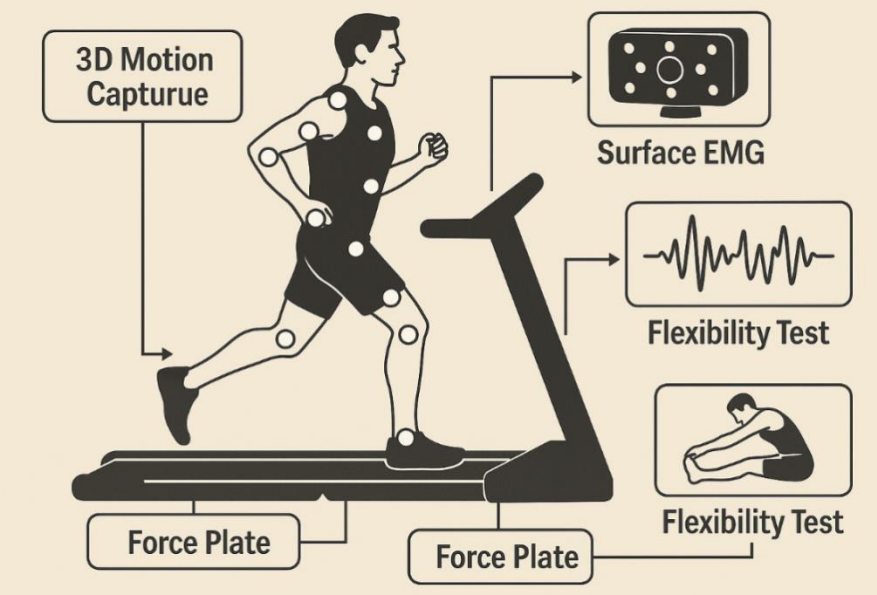

Figure 5. Integrated Biomechanical Testing Suite for Warm-Up Assessment

At the same time, vertical ground reaction force (vGRF) peaks were measured for every runner with a force plate inside the treadmill platform during their foot strike and when standing on the belt. It helped understand how strong the forces are in the legs, something that makes overuse injuries more common, including tibial stress fractures and patellofemoral pain. Surface EMG also helped record how each of the quadriceps, hamstrings and gluteus medius muscles were activated during dynamic movements. EMG signals measured during running were compared to MVIC to

control for intensity and the start and end of activation were studied throughout the movement. Finally, flexibility was evaluated in standard ways, with the sit-and-reach test measuring the posterior chain and hip abduction ROM checked using a goniometer. Examining these flexibility metrics made it simpler to judge any changes in joint flexibility that affect stride efficiency and risk of injury. By using both biomechanical and physiological assessments, it was possible to see how both yoga and traditional warm-ups would influence the preparedness of runners for an activity.

4. RESULTS AND DISCUSSION

Researchers found after the yoga-based warm-up that participants showed statistically significant changes compared to those who did the regular warm-up. The yoga group had much greater hip range of motion (49.3° ± 3.1°) than the control group (43.7° ± 3.5°), as proved by a significant p-value of less than 0.01. These findings showed that yoga group participants had smaller peak impact (2.35 ± 0.14 BW) than the control group (2.62 ± 0.18 BW) while trying to jump, showing better shock-absorbing quality ($p < 0.05$). Results from EMG testing revealed that the gluteus medius turned on stronger in the yoga practitioners (1.82 ± 0.10) than in the controls (1.54 ± 0.12) and the hamstrings also activated earlier, at 97 ± 12 milliseconds compared to the controls at 65 ± 11 milliseconds post-foot contact ($p < 0.01$). Back and pelvic control was better in the activity group during the stance phase, supported by watching their movements and the observed posture alignment.

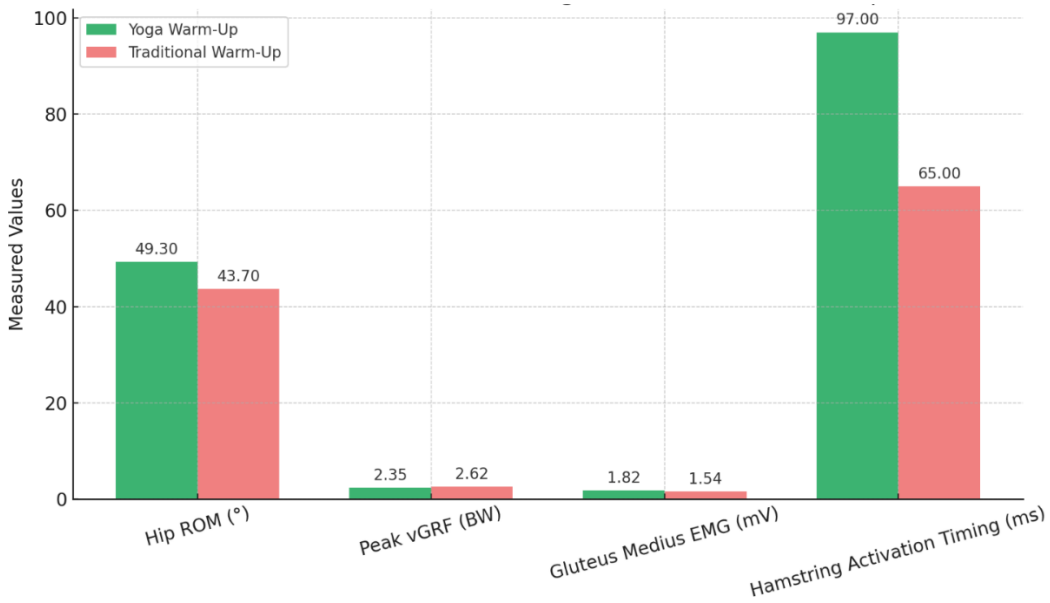

Figure 6. Biomechanical Outcomes: Yoga vs. Traditional Warm-Up

The findings confirm that doing yoga helps people get ready to run well. Greater hip ROM helps people move better and avoid extra movements linked to pain and injury in joints. If the hamstrings activate early and the glutes engage better, pelvic stability improves, the knees track correctly and risks like iliotibial band syndrome or patellofemoral pain are reduced. Because the vGRF was lower, the yoga group may have used a gentler, less forceful pattern to land which decreased the amount of force transferred through its lower limb. Grouped together, these changes in posture and position suggest the yoga warm-up may work to prevent injuries commonly linked to running. The study contributes new proof in favor of integrative warm-up and points to the usefulness of yoga in athletes' performance.

Table 3. Post-Intervention Biomechanical Results

Parameter	Yoga Group (Mean ± SD)	Control Group (Mean ± SD)	p-value	Interpretation
Hip ROM (°)	49.3 ± 3.1	43.7 ± 3.5	< 0.01	↑ Joint mobility
Peak vGRF (BW)	2.35 ± 0.14	2.62 ± 0.18	< 0.05	↓ Impact force
Gluteus Medius EMG (mV)	1.82 ± 0.10	1.54 ± 0.12	< 0.01	↑ Muscle activation
Hamstring Activation Timing (ms)	97 ± 12	65 ± 11	< 0.01	Earlier pre-activation for stability

5. CONCLUSION

The researchers found that using yoga movements before running improved biomechanical issues for recreational runners more than traditional dynamic warm-ups. Corrected postures focused on how the joints are aligned, how strong your core is and how muscles communicate with the nerves in yoga adds a solid base for your warm-up phase and makes running safer by easing hip movement, using muscles sooner to support the movements of your lower body and cutting down on excessive upwards force. All of these alterations help the animal to run more smoothly and safely. While traditional warm-ups mostly increase the heart rate and surface stretch, in yoga, your focus moves to deeper mobility and body awareness, leading to a healthy way to warm-up for sports. According to the study, including yoga as part of a warm-up routine can practically reduce Running people's risk of injury and help them perform better. Long-term tracking of injuries and application among top athletes could clarify how yoga-based warm-ups can be applied more widely in many fields of sports.

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