

Applications of Traditional Chinese Medicine in Exercise-Induced Fatigue and Sports Injuries

Junzhe Zhai

Vassar College, New York, USA
jzhai@vassar.edu

Abstract. Exercise-induced fatigue and sports injuries represent interconnected challenges for athletes: fatigue disrupts energy metabolism, redox balance, immune function, and endocrine homeostasis, elevating the risk of overuse injuries and delaying return to sport. Addressing this multisystem issue is crucial for safe and timely athlete rehabilitation. This paper explores traditional Chinese medicine (TCM) interventions for exercise-induced fatigue and sports-related injuries, focusing on five key approaches: herbal remedies, bioactive polysaccharides, Tuina, acupuncture, and integrated TCM-Western rehabilitation. Herbal interventions enhance glycogen storage, stabilize blood glucose, and reduce lactate, urea, and triglyceride levels; they also regulate redox balance (e.g., Danshen improves antioxidant enzyme activity), suppress pro-inflammatory cytokines to modulate immune function, and optimize the testosterone-cortisol balance for endocrine homeostasis. Bioactive polysaccharides like those from Cassia seed lower lactate levels, extending exercise endurance. Combinations of Astragalus, Codonopsis and jujube alter amino acid metabolism and gut microbiota composition. When paired with functional training, Tuina and acupuncture reduce pain, accelerate recovery, and enhance intervention efficacy. Integrated TCM-Western programs further boost functional improvements and athletes' readiness to return to play. Collectively, these findings demonstrate that TCM serves as an effective complementary approach, alleviating fatigue, facilitating injury recovery, supporting personalized care, and aligning with modern sports rehabilitation practices.

Keywords: Traditional Chinese medicine, exercise-induced fatigue, sports injuries.

1. Introduction

Exercise-induced fatigue affects many body systems and makes performance worse. It slows down recovery. It raises the chance of getting hurt while playing sports. This is especially true for overuse injuries and re-injuries when athletes' training load increases. The main problems center on energy use. They include a balance of oxidation and reduction. They involve the body's ability to fight off illness. They include steady hormone and nerve function. These issues then affect movement control. They change how pain is felt. They slow down tissue healing. In this situation, fixing just one thing doesn't work. This is true for both training and getting better after an injury. Traditional Chinese medicine has solutions. It uses plant-based treatments with many parts. It uses hands-on therapies. These work on all the problem areas mentioned. It alleviates symptoms while regulating

energy metabolism, inflammation, and hormone balance. This makes TCM a good choice for athletes. They need recovery that lasts. They need help with long-term tiredness that makes injury care harder. They need a safer way to get back to playing their sport.

Metabolomics studies look at how Danshen (*Radix Salviae miltiorrhizae*) affects energy use in rats that are completely worn out [1]. It makes the liver and muscles store more glycogen. It keeps blood sugar steady. It brings down triglycerides and blood urea nitrogen levels. It makes the body better at fighting damage from oxidation. It does this by lowering malondialdehyde. It raises glutathione and superoxide dismutase levels. It also reduces creatine kinase release. This points to less muscle damage from exercise.

Research focusing on the microbiome adds more to this picture [2]. A water extract made from *Astragali Radix*, *Codonopsis Radix*, and *Jujubae Fructus* together helps rats swim longer when carrying weight until they're exhausted. It changes waste products from the gut. It changes the types of bacteria in the gut. It affects how sphingolipids and glycerophospholipids are processed. It impacts how branched-chain amino acids and D-arginine or D-ornithine are used. These changes fit with the idea that the body and its microbes work together to create substances that fight fatigue. Getting hormones back to normal is another area of study. In a model where exercise causes low testosterone, the Bushen Yiyuan Recipe raises testosterone in the blood. It increases the ratio of testosterone to cortisol. It boosts proteins in Leydig cells that help make steroids. These include HMG-CoA reductase, StAR, and CYP11A1. This helps the body get back to a state where it builds up tissue after tough training [3].

Data from clinical rehabilitation shows added benefits. In a study with people who have knee osteoarthritis, researchers compared different approaches [4]. One group had acupuncture plus exercise rehabilitation. Another group had just had acupuncture. Another had just exercised. The group with both had the best short-term results. These results stayed better during follow-up. This shows TCM methods have a place in organized rehabilitation plans. Even with these findings, the research evidence is scattered. Studies are often small. Formulas, how much is given, and when it's given differ. Ways of measuring mechanisms and results aren't consistent. This makes it hard to use in team settings. It makes return-to-play decisions harder. This article sets goals for large-scale research across multiple centers.

2. Applications of Traditional Chinese Medicine in exercise-induced fatigue and sports injury

2.1. Applications of TCM for exercise-induced fatigue

Exercise-induced fatigue is a physical decline. It comes from long or intense physical activity. It doesn't just show as worse muscle performance. It also includes problems in the nervous system. It affects the immune system. It impacts the endocrine system [5]. Traditional Chinese medicine (TCM) eases exercise-induced fatigue. It helps with related injuries. It adjusts immune responses. This cuts down on inflammation. It makes energy metabolism better. This boosts endurance. It strengthens antioxidant capacity. This fights oxidative stress. It controls endocrine balance. This keeps the body in a steady state. It makes fatigue start later. It helps with recovery. It eases exercise-induced fatigue and injury.

Traditional Chinese medicine interventions can slow down fatigue. They do this by adjusting energy metabolism pathways. A metabolomics study looked at the Danshen extract. It showed the extract fixed metabolic problems in exhausted rats. It made the liver and muscles store much more glycogen. It kept blood glucose steady. It also cuts down metabolites linked to fatigue. These include lactate, blood urea nitrogen, and triglycerides [1]. This shows that Danshen makes energy supply

more efficient. It does this by helping the body use fat more. It also reduces too much breakdown of protein and glucose [1]. Polysaccharides from Cassia seed worked differently. They lowered blood lactate levels in tired mice. They also reduced lactate dehydrogenase levels. They made the mice swim longer while carrying a weight. This means the mice used energy more slowly [6]. A specific study employed fecal metabolomics and 16S rRNA gene analysis, which identified the effects of ACJ. ACJ is a combined extract of *Astragalus membranaceus*, *Codonopsis pilosula*, and jujube. It adjusted metabolic pathways. These include branched-chain amino acid metabolism and arginine/ornithine metabolism. It made gut microbiota work better. This helped mice have better endurance [2]. To sum up, traditional Chinese medicine treatment improves exercise endurance. It works in a bunch of ways. It increases energy reserves. It makes substrate use better. It optimizes metabolic pathways. This slows down fatigue.

Intense exercise can cause immune system problems. These include higher levels of pro-inflammatory cytokines. They also include fewer lymphocytes. This makes fatigue worse. Studies have looked at traditional Chinese medicine (TCM) interventions. They show TCM can ease exercise-induced fatigue. It does this by adjusting immune responses. One example is Shuyu Decoction. Reports say it lowers pro-inflammatory cytokine levels in tired rats. These cytokines include interleukin-6 and tumor necrosis factor- α . It lifts IL-10 levels. IL-10 is an anti-inflammatory cytokine. It also brings back normal counts of CD3⁺, CD4⁺, and CD8⁺ T-lymphocytes in the spleen [7]. This shows it reduces immune system problems from exercise. Water-soluble polysaccharides from *Semen cassiae* work too. They make B-cell and T-cell immune function better in tired mice [6]. Enhanced immune function reduces inflammation and subsequent tissue damage, thereby improving the body's resistance to fatigue.

High-intensity exercise creates too many reactive oxygen species (ROS). This leads to oxidative stress damage. This damage is thought to be one thing that causes exercise fatigue. Chinese herbal medicines can work against fatigue. They do this by making the body's antioxidant capacity stronger. They also reduce oxidative damage. Experimental studies focused on the Danshen extract. They showed that it cuts down lipid peroxidation products in exhausted rats. One example is malondialdehyde (MDA). At the same time, it raises glutathione (GSH) levels. It also makes antioxidant enzymes more active. Superoxide dismutase (SOD) is one of these enzymes. This makes the oxidative/antioxidative balance better [1]. *Semen cassiae* polysaccharides have similar effects. They made SOD and glutathione peroxidase (GPx) more active in tired mice. They also lowered MDA in the mice's serum [6]. These findings show TCM can ease oxidative damage from exercise. It does this by clearing out extra free radicals. It also boosts the body's own antioxidant enzymes. This slows down how fatigue gets worse.

Chronic intense exercise can throw the endocrine balance off. It drops androgen levels. Testosterone is one kind of androgen. It also raises stress hormones. Cortisol is one such hormone. This then makes recovery harder. It also weakens the body's ability to fight fatigue. Kidney-tonifying herbal formulas in TCM have an important role. They help fight fatigue. They do this by adjusting the endocrine system. Studies looked at the Bushen Yiyuan Recipe. They showed it made serum testosterone much higher in exercise-fatigued rats. It also raised the testosterone-to-cortisol ratio. At the same time, it increased the expression of steroidogenic proteins in Leydig cells. HMG-CoA reductase, StAR, and CYP11A1 are examples of these proteins [3]. Shuyu Decoction works in another way. It eases immune problems from exercise. It lowers IL-6, IL-1 β , and TNF- α . It raises IL-10 and T-cell types. This helps with recovery in an indirect way [7]. These findings show something important. TCM can boost levels of key endogenous hormones. Testosterone is one of these hormones. This lets TCM fix endocrine disturbances from exercise. It aids bounce back. It

keeps you from feeling wiped out. To conclude, TCM deals with exercise-induced fatigue. It tunes the immune system. It makes energy use run right. It responds to antioxidative stress. It modulates endocrine function. TCM uses a multi-target approach. It has a systemic regulatory way. This approach gives theoretical support. It also offers practical potential. Both aim to bounce back from post-work tiredness.

2.2. Applications of TCM for sports injuries

TCM fixes sports hurts good. It works great. Docs often mix two things. They mix Tuina and needles. They mix these with set moves. These moves aim to cut pain. They bring back a joint move. They grow muscle, too. They let players play safely again. Proof says these ways work. They fix sense-move control. They make the body feel better. They make joints steady. They push blood near the spot. They tune swelling. They help tissue fix. All this helps load steps. It helps bring back use [8-10].

It gives better joint scores from patients. It keeps balance gains as good as solo training. One plan ran eight weeks. Three groups came in. KOOS total scores rose in all groups. KOOS subscale scores rose, too. The mix plan gave bigger jumps. The jumps showed in the KOOS total scores. They showed in the daily activity subscales. They showed in sports/recreation subscales. Y-Balance Test scores jumped in every group. No big gaps sat between groups. This fits the wide retraining perks. The perks serve joint and soft-tissue hurts. Tuina plus staged moves helps. It steadies posture. It lifts joint work and cuts pain [8].

Other trial results show this [9]. Needles plus Tuina beat Tuina alone. It's better for easing symptoms. It's better for getting the function back. It also has fewer bad reactions. In groups with joint injuries, the combo plan helps. It makes the total success rate higher. It makes Lysholm scores go up. It makes SF-36 scores go up, too. It improves life quality. It makes VAS pain scores lower. This means steps are easier. Gains are clearer. This happens during slow load work. It happens when getting back to play early. Endpoints are right with the need to go back to sports.

Perioperative care and acute-on-chronic care have special needs. Adding acupuncture to regular physiotherapy helps in these cases. It eases pain quickly. It also means using less pain medicine. During postoperative recovery, some protocols include acupuncture. These protocols often show faster pain reductions. The reductions happen in weeks 2–4. There's also immediate relief after single sessions. This helps cut down protective co-contraction. It lets people do ROM work earlier. It improves how well people stick to therapy. In day-to-day rehab, this can go along with other things. These things are progressive joint mobilization. They are strengthening. They are gait retraining. This way, daily tasks can come back sooner. Sport-specific tasks can come back sooner [10].

Putting these together, combining Tuina and acupuncture with standard sports-injury care works. It is an effective way to deal with exercise-related injuries. Acupuncture helps with pain relief. It also improves circulation. Tuina supports soft tissue release. It helps make joint mobility better. When used together, they usually do more. They ease pain more. They help with functional gains more. They might also lower the risk of complications.

2.3. Integrated Chinese and western medicine for fatigue and injury care

Chinese medicine has its own ways. It uses needles and plant blends. It works on body balance. It brings back full function. Western care has its strong points. It spots injury fast. It gives quick help. It runs rehab drills. It follows clear rules. Putting both together should help. It should boost each part. It lifts the outcome. It cuts healing time. It trims drug side issues. One trial tested knee wear

[4]. It split folk into three lots. One lot got needles. One lot got rehab drills. One lot got both needles plus drills.

The results came out. The combined treatment group did better. It relieved pain much more. It improved its function much more. This was compared to the groups with single treatments. This shows something. Combining traditional Chinese and Western medicine might make treatment work better. It could happen through synergistic mechanisms. It's good for comprehensive intervention. This is for patients with chronic or moderate-to-severe conditions.

A study looked at this thing. It looked at muscle pain management [10]. This was during early rehabilitation. The rehabilitation came after anterior cruciate ligament surgery. Routine postoperative rehabilitation was given. Acupuncture was added to it. This cuts down pain scores a lot. The pain was in the medial thigh area. This happened 2 to 4 weeks after surgery. Patients felt pain relief right away. It happened after each acupuncture session. These results show something. They back up the advantages of TCM intervention. This is for controlling pain after surgery. It's especially good for using fewer Western medications. It also helps improve how well patients stick to rehabilitation.

Traditional Chinese medicine has another ability. It might help regulate immune function. This is after high-intensity exercise. A double-blind randomized trial was conducted, which investigated daily supplementation with Astragalus extract [11]. This was during high-intensity training. It kept the number of natural killer (NK) cells steady. It also kept regulatory T (Treg) cells steady. It made $\delta\gamma$ T cell activity stronger. It improved the IL-2/IL-10 immune factor ratio. This was in the Polish national rowing team. Studies indicate that Astragalus, a TCM supplement, effectively alleviates exercise-induced immune suppression. The suppression comes from intense exercise. This helps athletes recover fast. It also keeps immune function balanced.

To sum up, integrated traditional Chinese and Western medicine is used in sports medicine. This fits the trend of personalized treatment. It also fixes the limits of each approach alone. But current research has a focus. It mainly looks at evaluating clinical effects. Studies on mechanisms are not enough. Large-scale, multicenter trials are also lacking. Future research needs to grow. It should go deeper and cover more areas. This will push the evidence-based development. It's for integrated traditional Chinese and Western medicine. This is in the field of sports health.

2.4. Advantages, complementary roles and limitations of TCM in sports medicine

Traditional Chinese Medicine (TCM) has unique advantages in sports medicine. It puts special focus on holistic regulation and syndrome differentiation. These principles match well with exercise-induced fatigue. Fatigue affects multiple body systems. It doesn't just cause musculoskeletal strain. It also disturbs the immune, nervous, and endocrine systems. TCM doesn't target single symptoms. It sees fatigue as a systemic imbalance. Herbal treatments have special value. They use individualized prescriptions. They have low toxicity. This makes them good for long-term use. This provides sustained support during recovery. It's especially helpful when constitutional adjustment is needed. Full rehabilitation needs this adjustment.

Western care skips some bits. TCM steps in. Westerners read acute harm quickly. It fixes acute harm quickly, too. It still leaves gaps. It stalls with chronic tired spells. It misses mood shifts. It cannot bring back lost zip after hard work. TCM tools zoom in. They use needles and plant brews. They calm body aches. They refill the inner life force. This helps players bounce back. It helps the body. It helps the mind. Mind-body link plays a key part. It covers post-work bounce spots. These spots often stay hidden. It gives a fuller heal map.

But integrating TCM into modern sports medicine has challenges. Current research has issues. It often lacks standardized treatment protocols. It also lacks enough scientific rigor. Many clinical studies use small samples. Some leave out control groups. Others depend a lot on subjective outcome measures. These methodological problems cause trouble. They make it hard to build TCM's credibility. This is in evidence-based medical contexts. They also hold back its wider acceptance. This is especially true in international academic and clinical communities. Practitioners have inconsistencies. These are in diagnosis and treatment. This further limits the reproducibility of clinical findings. It also limits their reliability.

To fully unlock TCM's potential in sports medicine, future development needs a clear focus. It must link traditional knowledge with modern research methods. This focus covers specific actions. It means doing mechanistic studies. It also means running large-scale randomized controlled trials. Both help check if the treatment works. Building interdisciplinary research platforms is useful. Blended classes help. They let TCM docs, lab folks, and sport pros talk easily. New tools pop up. One is AI that spots body types. This opens doors to make plans that fit one person. It pushes old herbs into new sports care. It helps them travel around the world.

3. Conclusion

This paper assesses how traditional Chinese medicine handles exercise-induced fatigue and sport-related injury. It looks at coordinated biological mechanisms and clinical effects. From the synthesized evidence, herbal interventions have clear effects. They boost endurance. They improve fatigue indices. They do this by increasing glycogen reserves. They maintain blood glucose levels. They lower lactate, urea and triglycerides. They also optimize substrate use. Danshen extracts bring specific changes. They reduce malondialdehyde. They increase glutathione, superoxide dismutase and glutathione peroxidase. This shows a meaningful shift in oxidative balance. Cassia seed sugars act in a new way. They drop lactate and LDH. They add swim time in tired mice. Immune tweaks give big payoffs. They cut IL-6 and TNF α . IL-10 climbs. T cell numbers bounce back. The endocrine mix feels even. Testosterone climbs. Testosterone vs cortisol looks better. In rehab space, plans mix hands-on work with drills. Tuina and needles sit with set moves. Pain drops. Folks start motion work sooner. Feel and move control set tight. Patient scores climb. Surgery plans win extra. Plans that use needles give a quick pain drop. They lift patient follow-through. All these bits give solid proof for the wide view. This view fits the full body hit of sport tiredness. It gives care shaped for each one. Care that can cut rest days. Care that lets a safer step back to play. Important limitations remain. Many trials enroll small samples, use heterogeneous formulas or point prescriptions, vary dosing and session counts, and rely heavily on subjective outcomes, which constrains certainty and generalizability. Mechanistic resolution is incomplete for several botanical and procedural interventions. Future work needs clear priorities. It should focus on multicenter randomized controlled trials. These trials need harmonized endpoints. They should include objective performance metrics. They should also include objective biomechanical metrics. They need to integrate multiomics, microbiome, and metabolomics. These help make causal pathways clear. Certain things are necessary. Quality control for botanicals is needed. Dose-response programs for botanicals are also needed. Protocolized regimens for acupuncture and Tuina are required. Comparative effectiveness studies are needed, too. These should compare against best practice nutrition and rehabilitation. Implementation studies have value. Those with digital adherence support help. Those with AI-assisted pattern differentiation also help. These studies can improve precision. They can improve reproducibility. They also help standardize how traditional Chinese medicine is integrated. This integration is within contemporary sports medicine.

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