THE RETURN TO RUN PROCESS FOR FEMALES FOLLOWING A TIBIAL BONE STRESS INJURY: A SCOPING REVIEW.

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Tibial bone stress injuries (BSI) are common among female runners and have a high recurrence rate. Complete rehabilitation requires a successful return to running, but there is a lack of guidance for this. This review sought to establish the evidence supporting the return-to-running process following a tibial BSI in females. Sources were identified by searching databases using relevant terms. Study titles and abstracts were screened using inclusion criteria, and 48 articles were selected. An individualised graduated return-to-run programme should be instigated, beginning with walk-run intervals, and progressing running distance ahead of speed. The '10% rule' of graduated loading is not generalisable across all runners. Contributing factors to the initial injury should be addressed throughout the return-to-run process, including biomechanical factors and training errors.

KEYWORDS: running, stress fractures, recovery.

INTRODUCTION: Bone stress injuries (BSI) account for up to 20% of injuries seen in sports medicine clinics (Tenforde, Kraus, & Fredericson, 2016). Up to 95% of BSI occur in the lower extremities, with the tibia the most common location (Abbott et al., 2020). Lower extremity BSI are common among distance runners due to the repetitive loading of the sport, with more than one-third of long-distance runners experiencing lower extremity BSI, with females being particularly susceptible (Kelsey et al., 2007). Additionally, BSIs have one of the highest recurrence rates of all running-related injuries (Abbott et al., 2020). Following a tibial BSI, a critical component to complete rehabilitation is the successful return to running. While existing reviews have explored the general concepts of BSI management in females (Brukner & Bennell, 1997; Chen, Tenforde, & Fredericson, 2013), they have not been specific to running. There is a lack of information regarding when females should return to running, and a lack of guidance on how the process should take place. The aim of this review was to establish the research evidence to support the return-to-running process. This paper presents part of a larger study.

METHODS: The scoping review methodological framework proposed by Arksey and O'Malley (2005) and the JBI Evidence Synthesis (Peters et al., 2015) were followed for the design and reporting of this scoping review. Initial literature searches revealed no papers specific to tibial stress injuries in female runners, and as such the search scope was widened to include lower limb stress injuries, and any return to running-based activities. Combinations of the following keywords and constructs (i.e., Boolean phrases) were used: bon*, stress injur*/fracture*/reaction*, lower extremit*/limb*, leg*, tibia*, return* sport* play, training, activit*, run*. Studies were included if they outlined specific criteria prior to the introduction of running-related loads, or provided guidance on the process of returning to running-related activities, following a tibial or lower limb BSI. Studies that were specific to males, or detailed upper extremity, spinal or specific lower extremity BSI other than the tibia were excluded. An inductive thematic analysis was used to identify patterns, summarise consistent findings across studies, and generate common themes.

RESULTS AND DISCUSSION: The initial search identified 1040 studies, of which 48 studies met the inclusion criteria. Most articles (39) were reviews or clinical commentaries, three were retrospective cohort studies, two were randomised controlled trials, two were pilot studies, and

one prospective observational study and case series. All studies provided guidance on the return-to-run process, and from this four key considerations were identified.

Consideration 1 - Walk-run progression: The introduction of running loads following a tibial BSI should be achieved progressively to promote tissue adaption, whilst preventing injury reoccurrence. Most frequently it is recommended that this is achieved via a 'walk-run' progression on alternate days, gradually substituting walking with increasing time increments of running (Warden, Davis, & Fredericson, 2014). The specific length of running increments varied considerably among reviewed studies, however starting with 30-60 second increments, and progressing by 1-2 minutes, or an equivalent distance was often suggested. While these recommendations appear to be based on expert opinion, there is scientific basis for them. As little as a few minutes of impact exercise will stimulate bone formation, however bone cells become desensitised to prolonged mechanical stimulation (Boudenot, Achiou, & Portier, 2015). Bone is a living tissue that can fatigue quickly so incorporating rest intervals to prevent bone fatigue is important (Edwards, 2018). These points support the inclusion of a walk-run progression consisting of short-duration running periods initially, with adequate recovery interspersed throughout.

Consideration 2 - Progression of load: It was consistently recommended that pain should guide running load progression, specifically detailing that there should be no pain during or following running. When pain is present, athletes should rest until symptom resolution, then resume at a lower intensity level (Warden et al., 2014). Despite this consistent recommendation, pain is a complex phenomenon, it is not always closely linked to musculoskeletal damage, and is mediated by numerous factors (Marchand, 2020), therefore close monitoring and documentation of pain levels are required. It is recommended that distance is progressed ahead of speed following a tibial BSI. This is in agreement with recent guidelines for competitive runners (Hegedus, Ickes, Jakobs, Ford, & Smoliga, 2021), and mechanical fatigue tests indicating that stress fracture risk increases more rapidly with progressions in running velocity than running distance (Edwards, 2018).

Progressively increasing running distance by 10% per week, commonly referred to as 'the 10% rule', is recommended to prevent injury during normal training, but is also widely cited as a method of returning to running following a lower limb stress injury (Warden, Edwards, & Willy, 2021). While the origins of this principle seem to be expert opinion, there is no empirical research providing validation. It appears to have originated as a progression of distance, but has been extrapolated across different variable domains, including time and intensity, still without evidence (Warden et al., 2014). As with many other injury- and training-related variables, runners are likely to tolerate the progression of distance, time and speed differently (Warden, Edwards, & Willy, 2021), and based on this and the evidence available, the rate of progression should be individualised, and should take into account the pre-injury training status and the severity of the injury.

Consideration 3 - Running surface: A quarter of studies recommended initiating running on a treadmill (Brukner, 2000) due to the more compliant surface. Similarly, several other studies recommended avoiding hard surfaces (Romani, Gieck, Perrin, Saliba, & Kahler, 2002). There is some supporting evidence for these recommendations, as hard surfaces are associated with increases in loading-related variables associated with tibial stress fractures (Wang, Hong, Li, & Zhou, 2012). Additionally, running on a treadmill has been shown to evoke 'moderate' decreases in tibial loading compared with running overground (Milner, Hawkins, & Aubol, 2020). Conflictingly, some studies provide example return to run programmes on a running track (Allen et al., 2004), which are generally a hard surface. With the experimental nature of these studies, it may be that the surface recommendation was to control this aspect of the study, as opposed to a logical or even practical solution for return-to-running post-BSI. A small number of studies also recommended that it may be beneficial to initially avoid hills, as running on hilly terrain has been found to be associated with a higher incidence of stress fractures and

medial tibial stress syndrome. There is inconclusive supporting evidence regarding the effect of decline gradients, with some reporting that downhill surface gradients resulted in higher tibial acceleration (Chu & Caldwell, 2004), while others did not find such differences (Mizrahi, Verbitsky, & Isakov, 2000).

Consideration 4 - Biomechanical and strength factors: An essential component of return-to-running post-tibial BSI acknowledged by most studies was the need to address contributing biomechanical factors and muscle imbalances. There is evidence suggesting that greater peak hip adduction and rearfoot eversion angles (Milner, Hamill, & Davis, 2010), and tibial acceleration (Milner, Ferber, Pollard, Hamill, & Davis, 2006) are associated with the development of tibial BSI in female runners. As such running gait analysis, and potentially retraining, are appropriate steps for runners during the return-to-run process. Additionally, reduced lower limb muscle size and strength have been shown to be related to BSI risk in females (Beck, Rudolph, Matheson, Bergman, & Norling, 2015), specifically the calf muscles, as well as those supporting the hips and abdomen. To ensure muscles are prepared to provide active protection to the bone, resistance training, and ultimately plyometric strengthening, should be incorporated.

The majority of studies included in this scoping review were clinical commentaries or reviews containing considerable expert opinion, and will inherently have a high risk of bias. There were a lack of studies specifically detailing return-to-running post-tibial BSI, or those with female runners. While all reviewed provided some guidance on the process of returning to running following a tibial or lower limb BSI, no studies specifically compared approaches.

CONCLUSION: Although there is a lack of consistency across the evidence, this review highlights the fundamental principles of returning females to running following a tibial BSI. Four key areas of consideration have been identified. An individualised graduated programme should be instigated that begins with walk-run intervals, and progresses running distance, ahead of speed. Contributing factors to the initial injury should be addressed throughout the return-to-run process. In particular gait analysis to identify contributing biomechanical factors may be beneficial for the female runner. The addition of hip, abdominal and calf muscle strengthening are also important. Deciding when an athlete is ready to return to running is complex, and should be a shared decision between clinicians, coaches and athletes. Effective planning should involve addressing the athlete's risk profile and managing risk by balancing the athlete's interests and reinjury prevention.

REFERENCES

Abbott, A., Bird, M. L., Wild, E., Brown, S. M., Stewart, G., & Mulcahey, M. K. (2020). Part I: epidemiology and risk factors for stress fractures in female athletes. *The Physician and sportsmedicine, 48*(1), 17-24. https://doi.org/10.1080/00913847.2019.1632158

Allen, C. S., Flynn, T. W., Kardouni, J. R., Hemphill, M. H., Schneider, C. A., Pritchard, A. E., . . . Evans-Christopher, G. (2004). The use of a pneumatic leg brace in soldiers with tibial stress fractures--a randomized clinical trial. *Military Medicine, 169*(11), 880-884. https://doi.org/10.7205/milmed.169.11.880

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19-32. https://doi.org/10.1080/1364557032000119616

Beck, B. R., Rudolph, K., Matheson, G. O., Bergman, A. G., & Norling, T. L. (2015). Risk Factors for Tibial Stress Injuries: A Case–Control Study. *Clinical Journal of Sport Medicine, 25*(3). https://doi.org/10.1097/JSM.0000000000000126

Boudenot, A., Achiou, Z., & Portier, H. (2015). Does running strengthen bone? *Applied Physiology, Nutrition, and Metabolism, 40*(12), 1309-1312. https://doi.org/10.1139/apnm-2015-0265

Brukner, P. (2000). Exercise-related lower leg pain: bone. . *Medicine & Science in Sports & Exercise, 32*(3 Suppl), S15-s26. https://doi.org/10.1097/00005768-200003001-00004

Brukner, P., & Bennell, K. (1997). Stress fractures in female athletes: diagnosis, management and rehabilitation. . *Sports Medicine, 24*(6), 419-429. https://doi.org/10.2165/00007256-199724060-00006

Chen, Y.-T., Tenforde, A. S., & Fredericson, M. (2013). Update on stress fractures in female athletes: epidemiology, treatment, and prevention. *Current Reviews in Musculoskeletal Medicine, 6*(2), 173-181. https://doi.org/10.1007/s12178-013-9167-x

Chu, J. J., & Caldwell, G. E. (2004). Stiffness and damping response associated with shock attenuation in downhill running. *Journal of Applied Biomechanics, 20*(3), 291-308. https://doi.org/10.1123/jab.20.3.291

Edwards, W. B. (2018). Modeling Overuse Injuries in Sport as a Mechanical Fatigue Phenomenon. *Exercise and Sport Sciences Reviews, 46*(4), 224-231. https://doi.org/10.1249/jes.0000000000000163

Hegedus, E. J., Ickes, L., Jakobs, F., Ford, K. R., & Smoliga, J. M. (2021). Comprehensive Return to Competitive Distance Running: A Clinical Commentary. *Sports Medicine, 51*(12), 2507-2523. https://doi.org/10.1007/s40279-021-01547-1

Kelsey, J. L., Bachrach, L. K., Procter-Gray, E., Nieves, J., Greendale, G. A., Sowers, M., . . . Cobb, K. L. (2007). Risk factors for stress fracture among young female cross-country runners. *Medicine & Science in Sports & Exercise, 39*(9), 1457-1463. https://doi.org/10.1249/mss.0b013e318074e54b

Marchand, S. (2020). Mechanisms Challenges of the Pain Phenomenon. *Frontiers in Pain Research, 1*, 574370. https://doi.org/10.3389/fpain.2020.574370

Milner, C., Ferber, R., Pollard, C. D., Hamill, J., & Davis, I. (2006). Biomechanical factors associated with tibial stress fracture in female runners. *Medicine and science in sports and exercise, 38*(2), 323. https://doi.org/10.1249/01.mss.0000183477.75808.92

Milner, C., Hamill, J., & Davis, I. (2010). Distinct hip and rearfoot kinematics in female runners with a history of tibial stress fracture. *Journal of Orthopaedic & Sports Physical Therapy, 40*(2), 59-66. https://doi.org/10.2519/jospt.2010.3024

Milner, C., Hawkins, J., & Aubol, K. (2020). Tibial Acceleration during Running Is Higher in Field Testing Than Indoor Testing. *Med Sci Sports Exerc, 52*(6), 1361-1366. https://doi.org/10.1249/mss.0000000000002261

Mizrahi, J., Verbitsky, O., & Isakov, E. (2000). Shock accelerations and attenuation in downhill and level running. *Clinical Biomechanics, 15*(1), 15-20. https://doi.org/10.1016/s0268-0033(99)00033-9

Peters, M., Godfrey, C., McInerney, P., Soares, C., Khalil, H., & Parker, D. (2015). Methodology for JBI Scoping Reviews. In E. Aromataris (Ed.), *The Joanna Briggs Institute Reviewers' Manual 2015* (pp. 1-24): the Joanna Briggs Institute.

Romani, W. A., Gieck, J. H., Perrin, D. H., Saliba, E. N., & Kahler, D. M. (2002). Mechanisms and management of stress fractures in physically active persons. *Journal of athletic training, 37*(3), 306-314.

Tenforde, A. S., Kraus, E., & Fredericson, M. (2016). Bone Stress Injuries in Runners. *Physical medicine and rehabilitation clinics of North America, 27*(1), 139-149. https://doi.org/10.1016/j.pmr.2015.08.008

Wang, L., Hong, Y., Li, J.-X., & Zhou, J.-H. (2012). Comparison of plantar loads during running on different overground surfaces. *Research in Sports Medicine, 20*(2), 75-85. https://doi.org/10.1080/15438627.2012.660816

Warden, S., Davis, I. S., & Fredericson, M. (2014). Management and Prevention of Bone Stress Injuries in Long-Distance Runners. *Journal of Orthopaedic & Sports Physical Therapy, 44*(10), 749-765. https://doi.org/10.2519/jospt.2014.5334

Warden, S., Edwards, W., & Willy, R. (2021). Preventing Bone Stress Injuries in Runners with Optimal Workload. *Current Osteoporosis Reports, 19*(3), 298-307. https://doi.org/10.1007/s11914-021-00666-y

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