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The Effect of a Heel Insert Intervention on Achilles Tendon Loading during Running in Soccer

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ABSTRACT

The use of heel inserts has been shown to reduce the risk of sustaining Achilles Tendon (AT) injury in soccer. Likewise, heel lifts have been positively used in the treatment of Achilles tendon injury. Despite this evidence however, the mechanism behind such findings is still unclear. Consequently, this study recruited nine amateur male soccer players (83.4 kg (± 5.8), 23 years (± 3.7), Achilles tendon radius 19.13 cm (± 2.3), ankle width 0.072 cm (± 0.005), forefoot width 0.10 cm (± 0.005), size 10 feet) to collect kinetic and kinematic data during 10 running trials. Trials were performed on a third generation artificial turf whilst wearing a soccer boot with and without a 10 mm heel insert placed inside. From the data obtained, measures of Achilles tendon load and rate of loading were estimated. Paired t-tests with the combined participant data indicated that there were no overall effect of the heel-insert on peak Achilles tendon force ($p=0.25$), peak plantar flexion moment ($p=0.68$) or their corresponding loading rates ($p=0.92$ and $p=0.97$ respectively). Individual participant data did however show that for some the heel lift significantly reduced Achilles tendon loading, whilst others it was significantly increased. These findings therefore suggest that the response is highly individual. As such the application of heel lifts should be used with caution and the routine use of the inserts is not recommended.

KEYWORDS: Soccer; Participants; Amateur.

ABBREVIATIONS: AT: Achilles Tendon; UHEC: University Human Ethics Committee; 3D: Three-Dimensional; MRI: Magnetic Resonance Imaging.

INTRODUCTION

Soccer is an intermittent sport, made up of periods of low intensity activity such as running and short high intensity movements such as sprinting and jumping.¹ These repetitive activities place the performer at considerable risk of injury, particularly to the Achilles Tendon (AT).²⁻⁴

Susceptibility to AT pain and injury has been reduced *via* the use of commercially available heel inserts.⁵⁻⁷ Similarly, these devices have been used successfully in the treatment of AT injury.⁸ The mechanism behind the reduction in pain and injury is unclear, although one theory suggests that heel inserts change the orientation of the foot, raising the heel relative to the forefoot.^{9,10} Such orientation is thought to limit the calcaneal friction¹¹ and lower the maximum dorsi-flexion angle during the mid-stance phase of gait. This is believed to lessen the eccentric force and strain applied to the tendon, used to control the downward movement of the centre of mass.⁹

To quantify the mechanical change that occurs in response to a heel lift intervention,

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authors have measured external kinematic data.^{12,13} Others have estimated internal load^{14,15} although findings are inconsistent. Where differences in load have been shown,¹⁵ the magnitude of the heel lift required is greater (18 mm) than the lift found to reduce pain and injury (2.5-15 mm).^{7-8,10} Consequently, the mechanism behind the successful application of smaller heel inserts is still unclear.

One potential reason for the lack of supportive findings may relate to the measurements being used to quantify internal load. During running, it is assumed that between 85-100% of the net force generated during dorsi-flexion is from the triceps surae muscle group. This force is then applied *via* the AT to control the body's downwards movement.^{16,17} This measurement has therefore been used as an indicator of AT force.¹¹ Such measurement however, does not directly estimate AT force. Such calculation requires knowledge of both the force and the moment arm about the joint axis of rotation. Dixon¹⁸ presented a method that provides a reliable, subject specific estimate of the forces occurring in the AT. However, the accuracy of estimations using this approach has been limited by the use of Two-Dimensional (2D) estimates of both joint moment and AT moment arm. Another problem is that some studies have used barefoot trials with the heel inserts strapped to the foot.^{14,19} Due to participants being unaccustomed to such conditions, this may cause them to exhibit an altered running gait which may have resulted in the lack of significant findings observed.²⁰ Use of a soccer boot may therefore result in a more typical running strategy in those who are familiar with wearing the footwear. Alternatively, it is possible that the rate at which the AT structure is loaded rather than the peak force applied may be indicative of the mechanism behind reduced pain and injury.¹⁴ Individual mechanical differences in running gait are also an inherent source of variance in running patterns and may influence the user's response to the heel insert intervention. Consequently, some athletes have experience significant alterations in estimates of loading while others did not.^{11,14} Such a reason, may explain literature findings that describes no effect of a heel insert intervention on injury risk.²¹ As a consequence, looking at changes in AT load using pooled data may disguise the response of some individuals to the intervention.

The aim of the present investigation is to address the previous studies limitations, to assess the influence of a commercially available heel insert on peak plantar flexion moment and estimated AT force experienced by soccer players. Likewise, the relative importance of the average loading rate of these measurements is also investigated. It is hypothesised that the magnitude of peak plantar flexion moment and peak AT force, and the average rate of loading of these measurements, will be significantly reduced with the inclusion of the heel insert into a soccer boot when running at sub-maximal velocity.

METHOD

Nine male amateur soccer players (83.4 (\pm 5.8 kg), 23

years (\pm 3.7), Achilles tendon radius 19.13 cm (\pm 2.3), ankle width 0.072 cm (\pm 0.005), forefoot width 0.10 cm (\pm 0.005), size 10 feet) participated in this research investigation. All participants were heel-toe runners as indicated by distinct, double peaked force-time histories.²² All participants regularly participated in soccer and had recent experience of playing on a third generation artificial surface. Each participant was pain and injury-free for the three months prior to data collection. All participants provided written consent in accordance with the University Human Ethics Committee (UHEC).

Fifteen metres of third generation artificial shock pad (Arpro[®] Expanded polypropylene, 24 mm \pm 0.5 mm thick, Brock International) with a measured density of 65 g and a mechanical hardness of 1254.3 N (S.D. 48.5 N), was laid across a concrete laboratory floor. Placed upon the shock pad was a third generation turf of similar length (Astroplay MXS 40, Lano sports, Herelbeke, Belgium) and 10 kg·m² of sand mixed with 8 kg·m² of rubber crumb (5:4 ratio of sand to rubber). This was distributed as recommended by the manufacturer. An AMTI force plate (960 Hz) was positioned underneath the surface, approximately in the centre of the surface in both width and length. This was represented by a square marked by tape on the surface.

Participants performed 10 running trials upon the artificial turf surface as this is sufficient to obtain stable mean data for an individual.²³ The trials were performed whilst wearing a soccer boot with a moulded stud configuration (Adidas, Copa Mundial) as the control condition. For the experimental condition, a commercially available 10 mm Sorbothane heel insert (Sorbothane Shock Stopper, Sorbopro, Layland, Lancashire, UK) was placed inside each shoe. These conditions were tested for each participant in a randomised but balanced order.

The participants were asked to run the length of the 15 m artificial turf surface at a speed of 3.81 m·s⁻¹ (\pm 5%), monitored by photosensitive timing gates positioned one meter either side of the force plate. Sufficient time was given for the participants to establish a normal running style that ensured that they placed their right foot within the marked area without changing their normal stride pattern; they then continued their run to the end of the artificial turf surface. Participants adjusted their start position to ensure they were able to hit the centre of the marked area. All trials were monitored by the researcher and any trial that was not performed as directed or which were not at the correct speed were subsequently repeated.

To calculate joint moments, each participant wore retro-reflective markers on the right side of the body (Figure 1). An eight camera (Pulnix, TM-6703 progressive scan, 120 Hz) automatic tracking system (Vicon, Motus version 6.1, Englewood, CO, USA) was used to capture these markers and calculate their coordinates *via* the application of Direction Linear Transformation (DLT). These markers were then used to generate local reference co-ordinate systems based on the methods described by Soutas-Little, et al.²⁴ Quintic splines²⁵ were fitted to the raw



Figure 1: Images identifying marker placements used in the moment and moment arm calculation.

coordinates to obtain smooth continuous time histories for first and second derivatives. Acceleration data were calculated by the first central difference method.

The calculation of Three-Dimensional (3D) moments about the ankle joint used inverse dynamics and required the measurements of ankle joint and forefoot width to allow estimation of the ankle joint centre and the distal point of the foot segment. Ankle width was calculated by measuring the distance from the lateral malleolus to the medial malleolus with a calliper; forefoot width was measured as the distance between the first and fifth metatarsal at the widest location. This information was entered into the motion analysis software and joint centre and distal end points were calculated. When determining forefoot width, shoe material thickness was regarded as negligible. The inverse dynamics calculation also required additional knowledge of foot moment of inertia, mass and centre of mass. The foot mass and centre of mass were calculated using adult male cadaver data from Clauser, et al.²⁶ and moment of inertia data using the data provided by Whitsett.²⁷

To collect kinetic data, specifically force (F_x , F_y , and F_z), centre of pressure (a_x , a_y) and free moment (F_m), a force plate (AMTI, Newton, MA, USA) was used. The synchronous force and smoothed coordinate data were transferred from the Vicon Motus software into a Matlab program (Matlab, 7.0.4, The Maths Works, USA). Within the Matlab program, a code was written that interpolated the 960 Hz kinetic data to 120 Hz.

The calculation of three-dimensional moments occurring during plantar flexion was performed using code based on previously published methods.^{28,29} During the movements, the conventions of the calculated muscle moments were that a negative moment represented a resistance to extension of the segment. Three-dimensional AT force was calculated by adopting a similar technique to that developed previously.^{14,19} However, in the present study, a three-dimensional moment arm was calcu-

lated as the perpendicular distance between the ankle joint centre and the line of the AT represented by the two markers on the posterior aspect of the shank.

To account for the influence of the skin thickness that surrounds the tendon sheath and the radius of the external marker on the calculation of moment arm length, the radius of the marker and the skin covering the AT, was removed from the moment arm length prior to the calculation of AT force. To calculate the skin thickness, the radius of the AT width at approximately 5 mm from the AT insertion point was measured with a calliper for each subject. This was scaled using the skin thickness-AT radius ratio reported previously as 3.9 mm skin thickness when the AT radius was 7 mm.¹⁸ Peak plantar flexion moment and AT force were then determined from the calculated moment data. Average loading rates for each of these values were also calculated by dividing the peak moment and AT force by the time over which it had occurred.

For all participants, the mean and standard deviation of the 10 trials per condition was calculated and statistically compared using a paired t-test. Normality of data distribution was tested by determining skewness and kurtosis statistics. Individual participant data was also separately analysed by paired t-tests, comparing the corresponding trial data between the two conditions.¹⁸ The alpha level was set at 0.05 for all statistical tests which were performed using SPSS (IBM SPSS 21, New York, NY, USA).

RESULTS

The use of a 10 mm heel insert did not significantly reduce the estimated loading on the AT as indicated by the measurements of peak plantar flexion moment and peak AT Force. Similarly there were no significant differences observed for the measurement of average plantar flexion moment or average AT loading rates (Table 1).

	Control	Heel insert	P
Peak plantar flexion moment (N)	196.9±73.5	192.5±53.3	0.68
Average plantar flexion moment loading rate (Nm.s ⁻¹)	1612.2±526.6	1617.4±795.7	0.97
Achilles tendon force (BW)	6.6±3.0	7.3±4.0	0.25
Average Achilles tendon force loading rate (N.s ⁻¹)	255715.5±109306.8	259396.3±152438.3	0.92

Table 1: Mean±SD for plantar flexion moment and Achilles tendon force and corresponding loading rate data obtained whilst running in soccer boots with and without a heel insert.

Individual data analysis was performed by conducting separate paired t-tests for each participant and comparing between conditions using the corresponding trial data. This analysis indicated that there were significant individual responses to the heel insert. Some participants demonstrated a significant increase in loading and loading rate whilst others showed significant reductions; other participants showed no significant change in these measurements (Figures 2-5).

of previous studies to better understand the mechanism behind injury reductions with the use of heel inserts. Despite the use of three-dimensional moments and moment arm to calculate AT force, and the use of footwear, the data failed to support the hypotheses that peak plantar-flexion moment and peak AT force would be significantly reduced. Similarly, the rate at which the AT was loaded was also not significantly reduced when wearing the insert.

DISCUSSION

The aim of this study was to address the limitations

When looking at the individual data, a large range of peak moment and AT forces magnitudes was shown between participants. Such variation is unlikely due to the methodologi-

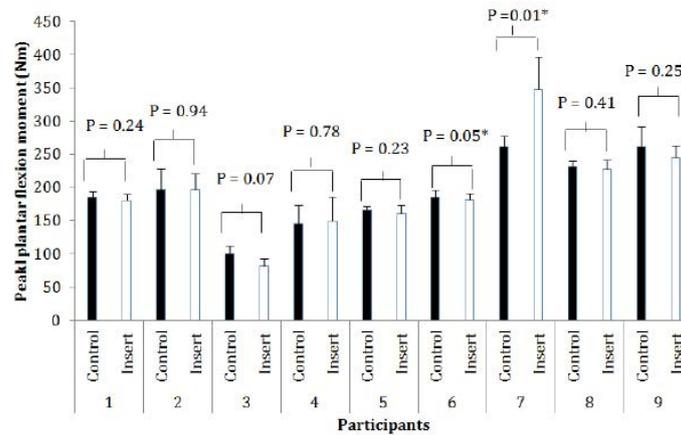


Figure 2: Means and standard deviations for each individual participant for the measurement of plantar flexion moment collected whilst running with the control (no insert) and experimental (insert) conditions. *denotes a significant difference at the p<0.05 level.

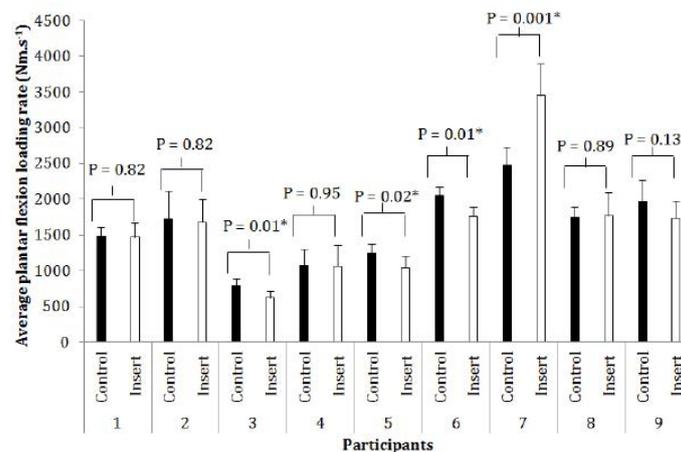


Figure 3: Means and standard deviations for each individual participant for the measurement of average plantar flexion moment loading rate collected whilst running with the control (no insert) and experimental (insert) conditions. *denotes a significant difference at the p<0.05 level.

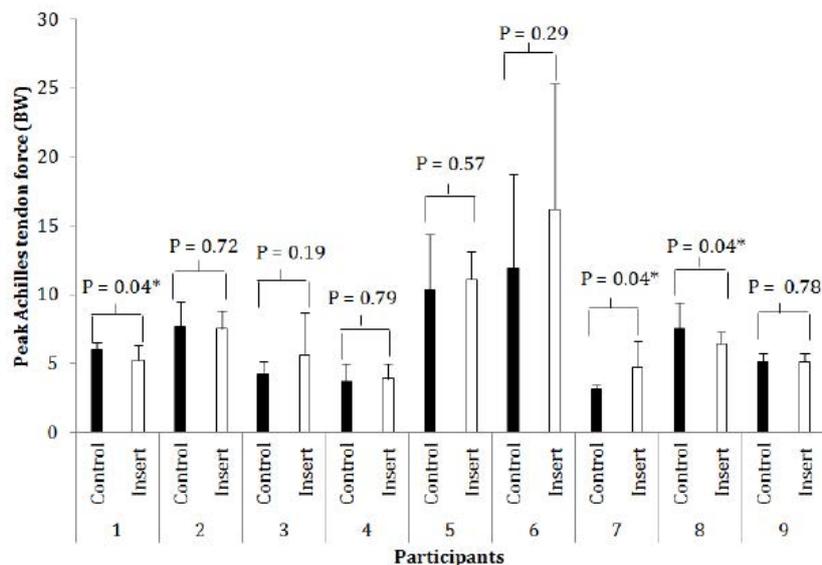


Figure 4: Means and standard deviations for each individual participant for the measurement of peak Achilles tendon force (measured in body weights, BW) collected whilst running with the control (no insert) and experimental (insert) conditions. *denotes a significant difference at the $p < 0.05$ level.

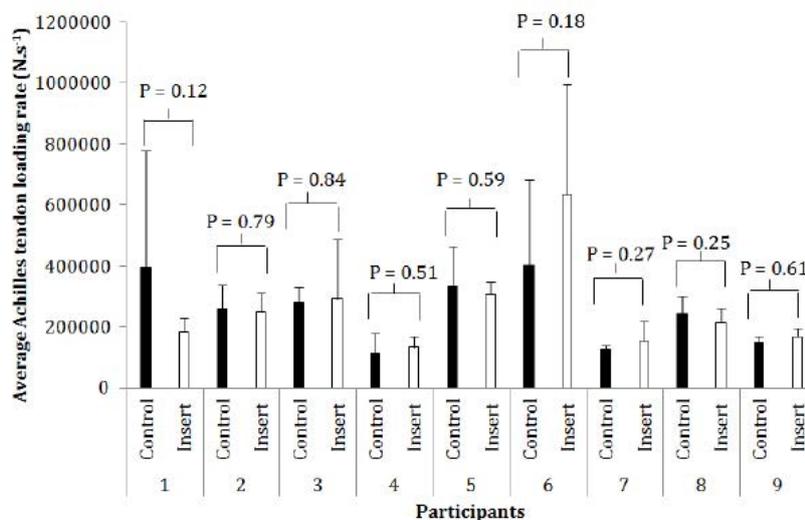


Figure 5: Means and standard deviations for each individual participant for the measurement of average Achilles tendon force loading rate collected whilst running with the control (no insert) and experimental (insert) conditions.

cal approach since the approach has been shown to be reliable.¹⁸ The estimation of AT force in the current study produced values of approximately 5 and 6 times the body weight of the participants, which is within the magnitudes reported by Komi³⁰ when *in vivo* AT forces were measured. Calculate moment arm lengths of between 30–40 mm¹⁹ are also comparable to those calculated by Magnetic Resonance Imaging (MRI).^{31,32} These are slightly longer than found previously¹⁵ although morphology differences in the participant groups could explain this. The approach did not account for any opposing (antagonistic) contribution of muscles such as the tibialis anterior which may contribute to a small underestimation of the loading.¹⁵ Likewise, failure to account for any additional assistance from the other plantar flexors to the net muscle moment may have influenced the magnitudes observed.¹⁵

However, the contribution of these muscles have been described as ‘trivial’ and activation profiles have been shown to be similar with and without larger inserts being applied.¹⁵ Study findings are also unlikely to have been influenced by differences in running velocity, since consistency in velocity was assured *via* the use of timing gates. All participants were also identified as heel-toe runners which meant differences in landing style are also unlikely to have influenced findings.

An alternative explanation for these findings may be that the response to the heel insert intervention is highly individual.^{11,14,19} The paired t-tests performed for each participant separately showed that despite the similar landing strategy, two of the nine participants exhibited significant differences in peak plantar

flexion moment. One of these participants exhibited greater peak moment and the other a decrease with the heel insert condition. The participant who experienced an increased moment also experienced a corresponding increase in AT force, suggesting the increased moment magnitude contributed to this rise in AT force. On the other hand, the participant who experienced a reduction in moment experienced no change in AT load. A shorter moment arm when running with the heel insert could explain this finding, resulting in comparable overall force. Further still, two participants showed significant reductions in peak AT forces with the heel insert, without a change in the moment magnitude, which again highlights the influence a change in moment arm can have on AT force. Various individual responses were also shown in the calculated loading rate for joint moments but not AT loading rate which may relate to reduced statistical power for this measurement. Such individualized responses are supportive of other research on heel inserts^{11,14,19} and indicate the mechanism behind injury reduction is varied. Whilst the participants in the current investigation were all injury free at the time of testing, individuals with reduced peak forces would therefore respond more favourably to the intervention when injured. By contrast, given sufficient repetition, those with increased loads may experience worsening of their symptoms if injured. Treatments using a heel insert should therefore be performed on an individualised basis and regular monitoring of the clinical responses (i.e. symptoms getting worse) is needed.¹⁴

It has been suggested that those with highest AT force under the no heel insert condition, experience the significant reductions with heel-insert when those with lower forces do not.¹⁴ This trend was however not supported in the current investigation. Whilst heel-toe landing strategy was consistent, the individual response may relate to specific physiological differences such as flexibility at both the ankle and knee joint due to the bi-articular nature of the gastrocnemius muscle. Future studies investigating the protective and rehabilitative benefits of heel inserts need better understanding of these differences to investigate the causative factors for individual response.

It is also important to acknowledge that the aetiology of AT injury has been related to a change in calcaneal friction rather than force magnitude. Reinschmidt and Nigg¹¹ postulated that reduced inflammation may occur when the calcaneus is lifted with respect to the tibia. Such suggestion may however only explain the treatment benefits for those with insertional Achilles tendonopathy.¹¹ It has also been found that the amount of strain of the muscle resulting from the applied force is significantly reduced with a heel insert. This suggests that rather than reducing overall force, the heel insert lowers injury risk by reducing that amount of lengthening the tendon undergoes.^{12,15} Another problem that arises from the use of peak plantar flexion moment and AT force is that the magnitude only refers to axial loads or a stretching of the AT.¹¹ The change in heel height may change non-axial loads, such as shear and/or bending. This may be affected by the amount of pronation that occurs which has been shown to be influenced by heel height.^{33,34}

In conclusion, the investigation reported no significant change in group data when a 10 mm heel insert in used, suggesting that measures of Achilles tendon loading could not indicate the mechanism behind reduced injury incidences. Therefore, these results do not support the original hypothesis. However, single subject analysis suggest that the response is individual and that reduced loading is a suggested mechanism behind the reduction of injury risk and successful treatment for some. Caution is recommended however, since significant increases in peak AT forces were shown for some individuals, suggesting that for these individuals, an increased risk of injury or worsening of symptoms can occur with the application of a heel lift intervention.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Brief Report

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The Interventional Use of Water Treadmill Running During Long Periods of Injury

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ABSTRACT

The aim of this brief study was to establish the efficacy of waist depth water Aquatic treadmill (ATM) running during a 28-day injury period where normal land based training was not possible. Synchronized tri-axial accelerometers were used to identify running dynamics while expired air and heart rate were sampled on a breath-by-breath basis for physiological variable collection throughout a 15-minute sub-maximal constant speed trial performed pre-injury, 28-days following initial injury (ATM training), and a further 10-days following a return to normal land based training. Water treadmill running altered spatio-temporal parameters that positively enhanced measures of running efficiency while reducing stress on the passive structures of the lower limbs. On cessation of ATM spatio-temporal parameters returned to normal while running efficiency remained greater than pre-injury values. As such, if water treadmill running does not hamper the rehabilitation process or negatively alter running technique it is a useful means of maintaining fitness following injury.

KEYWORDS: Immersion; Gait; Injury; Efficiency; Water Treadmill.

ABBREVIATIONS: ATM: Aquatic treadmill; LTM: Land Treadmills; TRIMP: Training Impulse; RER: Respiratory Exchange Ratio.

INTRODUCTION

The repetitive nature of endurance running¹ and the transference of energy generated on impact with the ground^{2,3} is entwined with reported high incidences of lower extremity injuries.⁴⁻⁶ Previous reports suggest incident rates of those embarking on training for distance events are between 2.5-12.1 per 1,000 h⁶ with specific reports regarding those training for a marathon equating to >70% of participants.⁷ Such odds, makes training for events like the marathon a particularly risky business and there seems to be no distinguishable preference to individual performance status.⁸

As such the injured runner faces the predicament of a cessation in training, the onset of an initial negative psychological/emotional response(s),⁹ followed by differing degrees of physiological and subsequent performance detraining effects.¹⁰ Justifiably, such emotional responses are based on the substantiated and well documented understanding that physiological function decreases after as little as 3 weeks cessation^{11,12} due primarily to cardiovascular system changes.¹³⁻¹⁵ However, the differentiation between cessation of training and a reduction in training load (tapering response) in terms of physiological and performance response is critical. Tapering involving the reduction of training load, is associated with performance improvement.¹⁵ This is due to reductions in physiological and psychological stress which increase peripheral fatigue. As such, any intervention that can stimulate a physiological response close to normal training conditions in an injured runner, while not hampering the recovery process, must be seen as positive to an otherwise quite traumatic situation.¹⁶ It has been suggested that deep water exercise¹⁷⁻¹⁹ or other non-impact exercise¹⁸ offers sufficient stimulus to preserve prior

fitness levels amongst healthy participants. However, no assessment of the impact of such an intervention on running dynamics has been performed. More recently, water immersed treadmill exercise has become popular as a low risk, more specific mode of training for endurance runners. Aquatic treadmill (ATM) running has been shown to unload vertical forces by an estimated 70% compared to Land Treadmills (LTM) due to decreased velocity at impact, hydrostatic pressure and the buoyancy effect of water immersion.²⁰ Importantly, it is suggested that the anatomical structures that benefit from the reduced load of ATM training are the hip, knee and foot joints along with the passive structures of the lower limbs. These normally take the strain in land based running^{21,22} and are most at risk of injury amongst endurance runners.⁶ Therefore, it is feasible to suggest that ATM running could be used as a means of rehabilitating muscle movement patterns without the risk of re-occurring injuries. Furthermore, the understanding that ATM compared to LTM running can result in greater metabolic costs²³⁻²⁶ suggests it could be used as a means for maintaining specific cardiovascular fitness and therefore performance during periods of injury amongst runners. However, such suppositions are unsubstantiated for an injured athlete(s) and it is unknown how such periods of training might effect normal running dynamics on return to land based training. Nevertheless, to be of real benefit to athletes trying to maintain fitness during normal training cessation there would have to be similar physiological demands of exercise without incurring the same risks as land based training.

Therefore, the purpose of this case report is to establish the efficacy of waist depth ATM running throughout a period (28 days) of injury to the lower leg, where normal land based running was not possible. As such the emphasis was to assess and compare post-injury LTM running spatio-temporal parameters and the subsequent physiological responses with pre- injury measures at a sub-maximal running velocity.

METHODS

Participant

One nationally competitive masters distance runner (height 172 cm; body weight (land) 58.4 kg; body weight (water, waist depth) 28.4 kg; land based BMI 19.74; $\dot{V}O_2$ max 68 ml·kg⁻¹·min⁻¹; HR_{max} 168 bpm) with a 5,000 m treadmill time trial performance of 14 min 58 s prior to injury and who had prior experience of LTM and ATM running, participated in this case study after giving written consent in accordance with the University Human Ethics Committee. The participant was part of a separate study investigating running dynamics during LTM and ATM²⁰ but presented themselves with an acute injury soon after completion of the initial study. The injury was diagnosed by a qualified physiotherapist as a Grade 2 (2nd degree moderate) calf strain with a loss of strength and inability to continue any form of land based running or similar activity. Treatment of the diagnosed injury involved 2 days of complete rest including application of the RICE principle, a return to exercise based on

pain free experience, and self application of massage as directed by physiotherapist.^{27,28}

Training

Training prescription was not controlled during the case report period but the participant was asked to manage training in relation to a non-painful intensity and/or volume during the injury rehabilitation period. In this respect all training performed was of a low intensity and of a continuous nature. An electronic training diary (RubiTrack3, version 3.4.7) was kept prior to and throughout the whole period of the case study and training load (a measure of training intensity and volume) is expressed as Training Impulse (TRIMP).^{29,30}

$$\text{TRIMP} = \text{Exercise Duration (mins)} \times \left[\frac{(\text{HR}_{\text{ex}} - \text{HR}_{\text{rest}})}{(\text{HR}_{\text{max}} - \text{HR}_{\text{rest}})} \right] \quad (\text{Eq. 1})$$

Where, HR_{ex} is the mean HR for the training session; HR_{rest} is the participants resting HR; HR_{max} is the participants maximum HR.

Figure 1 highlights the participant's weekly training load throughout the period of the case study. The training load values during these weeks translated to weekly distances: 119.0; 74.2; 83.6; 77.9; 172.9; and 184.7 km with a corresponding average heart rate of 125; 121; 124; 121; and 130 bpm, respectively. This data indicates that the type of training undertaken throughout the whole period was in the low intensity, high volume category.

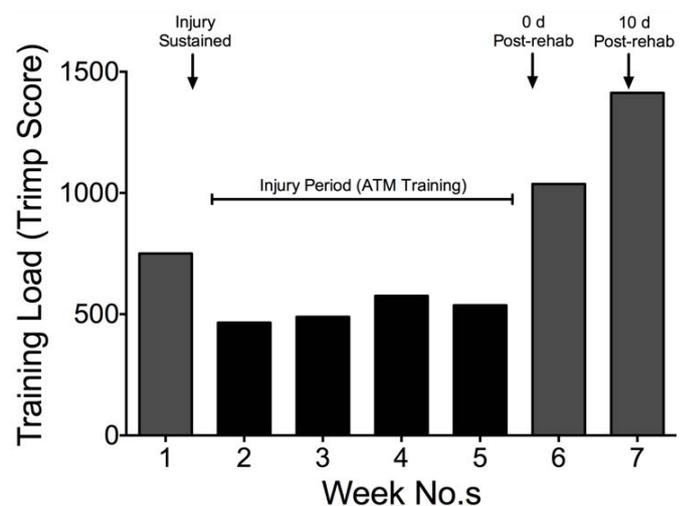


Figure 1: Participants training load (TRIMP) throughout the period of the case study.

Procedures and Measurements

On arrival at the laboratory the participant was measured in order to determine the water depth for ATM (height from floor to anterior superior iliac (cm) which was kept constant throughout trials) and weighed (dry land body weight and

body weight (kg) at the predetermined immersion depth).

Following this the participant was fitted with the wireless, tri-axial accelerometer (Emerald, APDM, OR, USA), used to measure accelerations (reported accuracy $0.0012 \text{ m} \cdot \text{s}^{-2} \cdot \sqrt{\text{Hz}^{-121}}$) of the distal anterolateral aspect of the right tibia, selected to minimize soft tissue oscillations during impact²¹ and not infer with gait patterns during ATM running. The accelerometer was packed tightly into a waterproof sport armband housing (h_2oaudio , San Diego, CA, USA) and secured tightly. In addition to this the participant was connected to an automated portable gas analyzer (K42b, Cosmed, Italy) that sampled expired air on a breath-by-breath basis; an ANT+ heart rate monitor – Run strap plus transceiver (Garmin Forerunner 620, USA).

Following a warm-up and familiarisation period of 5 min at $<2.78 \text{ m} \cdot \text{s}^{-1}$ prior to both conditions, the participant ran at the required speed of the trial for 2 min in order to eliminate any differences between oxygen kinetics that may occur at the onset of exercise due to water immersion.³¹ The experimental protocol consisted of the participant running at $2.83 \text{ m} \cdot \text{s}^{-1}$ over a 15 min period, on both LTM (TechnoGym, Italy) and ATM (O'Leary Engineering, New Zealand), and separated by a 15 min recovery period. The ATM water depth was set to anterior supra iliac (105 cm) with water temperature maintained at $21 \text{ }^\circ\text{C}$ throughout all trials. It was felt that the selected water depth offered the least disturbance to arm swing whilst running and has previously been shown to balance the effects of increased resistance with increased buoyancy in terms of work done comparable to LTM.²⁵ Each treadmill was calibrated prior to each trial, to the same speed (Eq. 1) by using a magnetic switch that was triggered with each belt revolution.

$$\text{Treadmill speed (km} \cdot \text{h}^{-1}) = (((\text{Treadmill Belt length (m)} \cdot \text{revs} \cdot \text{min}^{-1}) / 1) \cdot 60) / 1000 \quad (\text{Eq. 2})$$

The different trials were distinguished by the duration of time (Days) in relation to the participant rehabilitation status, and included: non-injured (Day 0); complete rehabilitation, post injury (Day 28); post injury (Day 38). Each condition (LTM and

ATM), within trial, was performed in the same order to enable comparison between pre-injury and post injury values.

Outcome measures

All variables were logged over the full 15 min period. Accelerometry data (128 Hz) was processed using MATLAB R2014a, analyzed for total (XYZ) accelerations ($\text{m} \cdot \text{s}^{-2}$) allowing identification of the precise times of foot contact, peak impact and toe-off for each stride (Figure 2).

From these accelerometric outputs the following variables were measured or calculated for the complete 15 min period: a) ground contact time (t_g), defined as the time (s) from initial foot contact to the point of toe-off⁵; b) swing time (t_{sw}) defined as the time (s) from toe-off to initial ground contact of consecutive footfalls of the same foot⁵; c) stride duration defined as the time (s) taken for consecutive peak impacts of the same foot; d) stride frequency (S_{freq}) defined as the number of strides taken per second (Hz); e) stride length (m) was calculated by dividing treadmill speed ($2.83 \text{ m} \cdot \text{s}^{-1}$) by S_{freq} (Hz).

Expired respiratory gases collected breath-by-breath enabled the calculation (CPET suite, version 10.0e, Cosmed, Italy) of: the body's rate of oxygen utilisation ($\dot{V}\text{O}_2$, expressed $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$); the ratio of the carbon dioxide produced to oxygen used (Respiratory Exchange Ratio, (RER)); the amount of air expired from the lungs during a minute (minute ventilation (V_E , $\text{L} \cdot \text{min}^{-1}$); and breathing frequency (Rf, breaths per minute).

Spatio-temporal and physiological data were analyzed collectively as a means to determine efficiency of the two conditions *via* the oxygen consumed per stride ($\dot{V}\text{O}_2$ per stride, ml).³²

Data Analysis

Data generated for all descriptive dependent variables was collected over the complete 15 min period and analyzed over 5 min epochs for physiological and spatio-temporal variables. Data for all variables is expressed as the mean over the

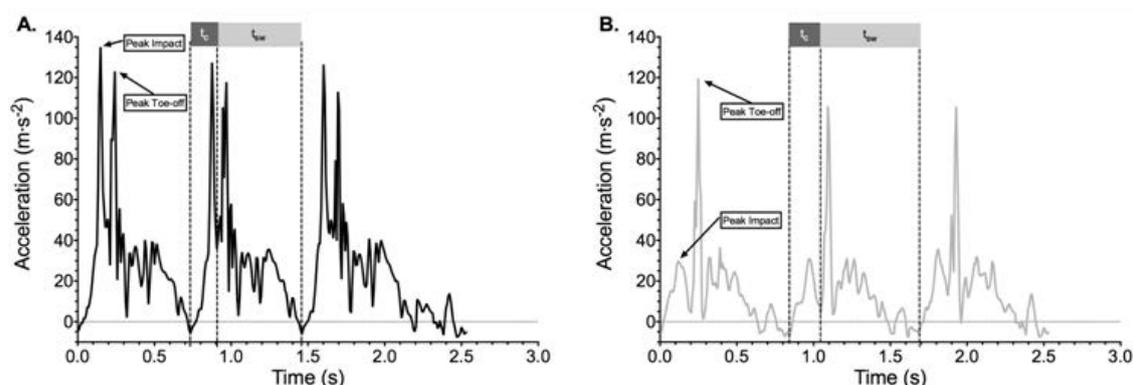


Figure 2: Accelerometer output for total accelerations (XYZ-planes) versus time (s) at the foot for the LTM (A) and ATM (B) conditions. Ground contact (t_g) and swing time (t_{sw}) are highlighted along with peak impact and peak toe-off.

specific epochs unless otherwise stated.

RESULTS

Running Dynamics

Data analysis for each 5 min epoch showed no changes over time within and between each trial for basic measures of running dynamics for either LTM or ATM. Therefore, subsequent analysis is presented as an overall comparison between trials (Day 0, 28, and 38) and conditions (LTM vs. ATM).

Stride duration (Figures 3A and 3B) was considerably different between LTM and ATM from the onset (0.737 ± 0.003 vs. 0.884 ± 0.012 s, respectively) of the case report, but this difference was reduced following 28 d of ATM training (0.778 ± 0.007 vs. 0.840 ± 0.013). Interestingly, the analysis at 10 d post-injury

(Day 38) shows a reduction in LTM stride duration but an increase in ATM stride duration. Percentage differences equated to 120.0 ± 1.2 , 108.0 ± 1.8 , and $122.8\pm 0.6\%$, for the three time points respectively. Key components of gait analysis (t_c and t_{sw}), presents a slight parabola effect for LTM (0.205 ± 0.007 , 0.230 ± 0.002 , and 0.209 ± 0.007 s; 0.528 ± 0.008 , 0.550 ± 0.002 , and 0.544 ± 0.008) and an inverse parabola for ATM (0.211 ± 0.009 , 0.176 ± 0.015 , and 0.208 ± 0.004 ; 0.689 ± 0.010 , 0.677 ± 0.010 , and 0.736 ± 0.012) for Day 0, 28, 38 time points for both t_c and t_{sw} , respectively (Figures 3C-3F).

Physiological Variables

Data analysis showed no changes over 5 min epochs for heart rate and $\dot{V}O_2$ within trials (Figure 4) but highlights considerable differences in work done between conditions (LTM and ATM). Overall trial analysis identifies a reduction in aver-

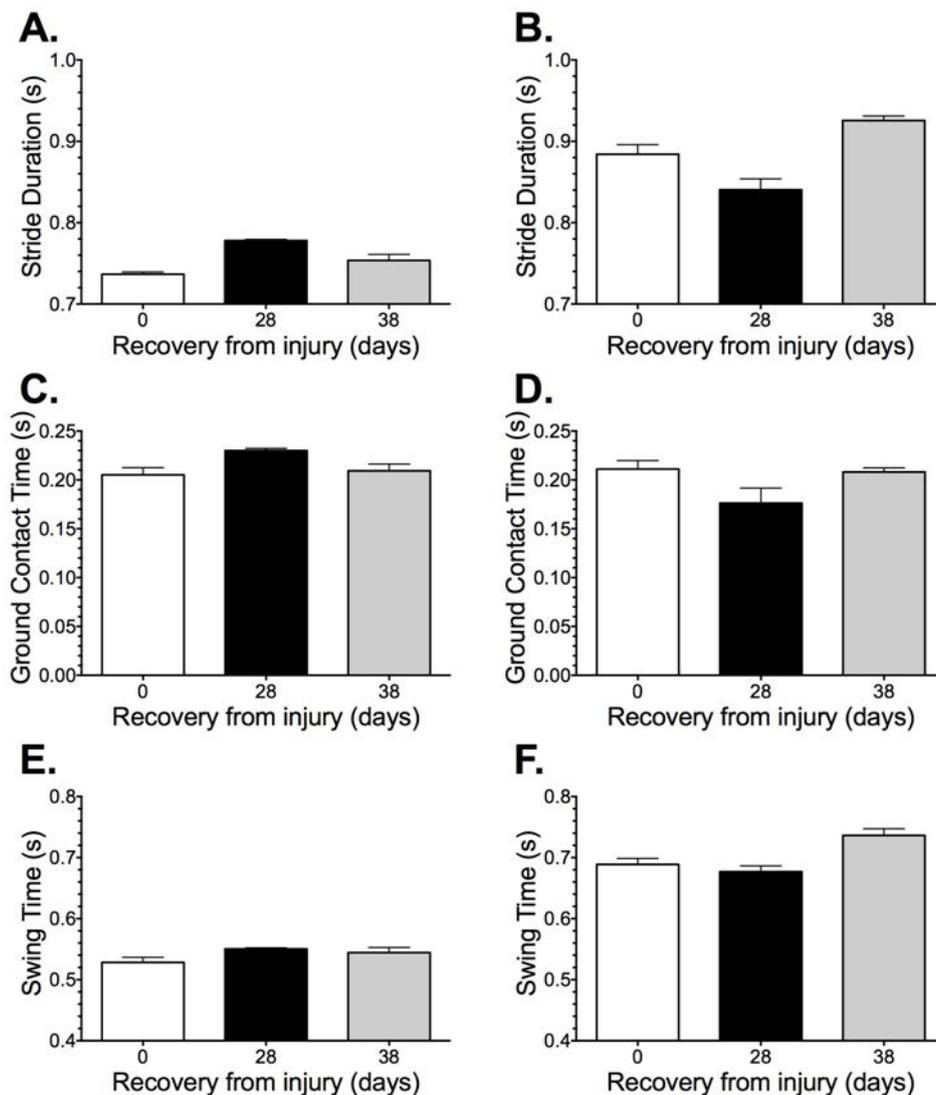


Figure 3: Mean±SD, for specific components of stride presented in time (s) and separated by condition (LTM and ATM) over each trial specific to the injury recovery time point reference. Where, A. Total stride duration (LTM), B. Total stride duration (ATM), C. Ground contact time (LTM), D. Ground contact time (ATM), E. Swing time (LTM), F. Swing time (ATM).

age heart rate for both conditions (LTM and ATM) following the period of ATM training in both the 28 d and 38 d trials when compared to the pre-injury trial (102 ± 1 , 104 ± 1 , and 107 ± 1 for LTM; 127 ± 1 , 121 ± 1 , and 121 ± 2 for ATM), respectively. While there was an initial decrease in $\dot{V}O_2$ values from pre-injury (0 d) to 28 d, the 38 d trial suggests a return to pre-injury values (38.6 ± 1.4 , 31.2 ± 0.8 , and 36.1 ± 1.0 for LTM; 55.0 ± 1.0 , 40.9 ± 0.3 , and 48.7 ± 1.6 $\text{ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ for ATM), respectively.

As there were no differences between 5 min time periods and conditions it was decided to combine physiological data within conditions (LTM+ATM). This analysis (Table 1) highlights the overall differences between trials in relation to pre-injury testing (0 d) and the two trials post rehabilitation (28 and 38 d). Key differences include an increased efficiency at 28 d post rehabilitation expressed through variables the variables: $\dot{V}O_2$, \dot{V}_E , $\dot{V}O_2$, heart rate, oxygen pulse and $\dot{V}O_2$ per stride (Table 1). While, after a 38 d resumption of normal land based training the aforementioned variables had returned to values similar to pre-injury (0 d) levels and thus showed significantly different to 28 d post rehabilitation (Table 1).

DISCUSSION

The aim of this brief report was to establish the efficacy of waist depth ATM running throughout a period (28 days) of injury to the lower leg, where normal land based running was not possible. As such the emphasis was to assess and compare post-injury LTM running spatio-temporal parameters and the subsequent physiological responses with pre-injury measures. The main findings were: (a) Spatio-temporal parameters (stride duration t_c and t_{sw}) increased during LTM and decreased for ATM following the rehabilitation period; (b) Improvements in measures pertaining to physiological efficiency following the rehabilitation phase of ATM training; and (c) Spatio-temporal and physiological changes showed signs of returning to pre-injury

status following 10-d of normal land based training.

Under normal circumstances the injury experienced would mean that the participant would have had to stop all running activity. However, the water treadmill enabled training at a reduced level and as such could be classified as a taper rather than an injury caused cessation (Figure 1). In agreement with running specific tapering strategies used by Olympic athletes to enhance performance.³³ The participants sustained 60-70% of their normal dry land pre-injury training volume (Figure 1), but excluding the normal. High intensity interval training including in such tapering protocols.³³ It is possible that cessation of such work could affect maximal physiological capacity, spatio-temporal metrics and the associated measures of performance. However, due to potential for re-injury such training was not recommended or tested.

The data collected in this case study supports the increased metabolic cost of running during ATM at the same speed (Figure 4) and is likely a result of increased hydrodynamic resistance,²⁶ identified as an "added-mass".³²

Analysis of the time course data prior to and following injury provides contrasting results with regards to technical changes highlighted by spatio-temporal metrics (Figure 3). The ATM condition suggests adaptation to more efficient water immersed running technique following prolonged exposure to ATM training without land-based training. This would occur in order to overcome hydrodynamic resistance exposure during ATM²⁶ and is reflected by physiological values associated with metabolic efficiency (Table 1). The change in running technique during ATM condition following injury also coincided with changes to LTM running. This included an, increased stride length primarily due to increased ground contact time, and coincides with reduced metabolic cost of LTM running following a period of ATM training. It is proposed that the increased resistance to limb

	0 d	28 d	38 d
$\dot{V}O_2(\text{ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1})$	46.85±9.11	36.07±5.33	42.37±7.02
$\dot{V}_E(\text{L}\cdot\text{min}^{-1})$	78.77±18.39	78.59±23.06	74.64±15.53
$\dot{V}_E:\dot{V}O_2$	28.92±1.42	36.45±5.57	30.03±1.34
$Rf(\text{b}\cdot\text{min}^{-1})$	39±1	40±4	35±3
Tidal Volume (L)	2.03± 0.48	1.91± 0.38	2.09±0.26
HR (bpm)	117± 11	112± 10	113±10
O_2 Pulse ($\text{ml}\cdot\text{bpm}^{-1}$)	22.92±2.44	18.91±1.12	21.80±1.79
$\dot{V}O_2$ per stride (ml)	0.62±0.18	0.48±0.09	0.58±0.16
No. Strides per Breadth	1.93 ± 0.22	1.86±0.27	2.08±0.41

Table 1: Mean±SD for overall (condition) effect on physiological variables.

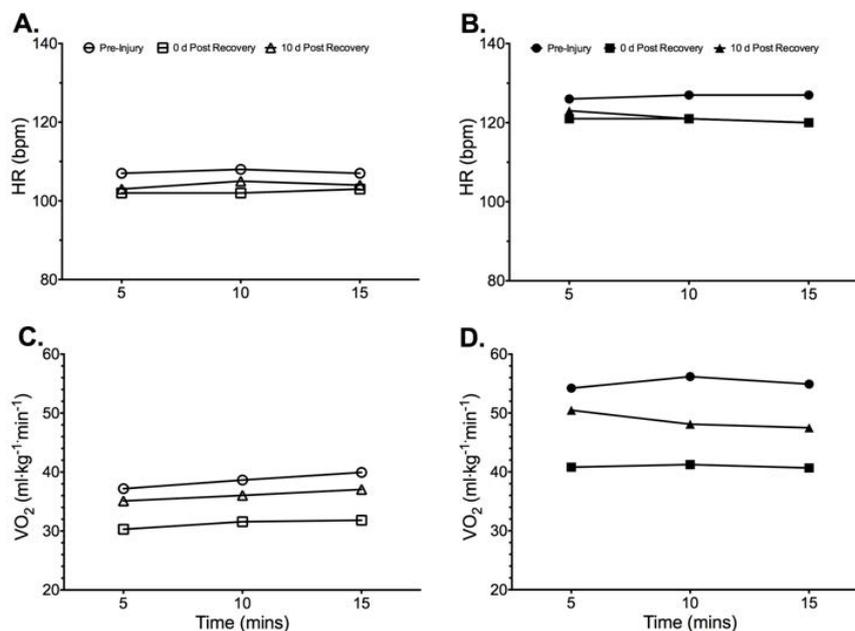


Figure 4: Mean physiological data for each 5 min epoch within each trial (reference time point in days since recovery from injury) and separated for condition (LTM and ATM) for: A. Heart rate LTM; B. Heart rate ATM; C. VO₂ LTM; and D. VO₂ ATM.

extension occurring during ATM afforded the participant greater force production capability of the limb extensors but requires further research.^{34,35}

Importantly, the return to land training (LTM) resulted any changes as a result of the ATM rehabilitation period quickly reverted to pre-injury values. This suggests that athletes requiring several weeks of rehabilitation from injury could utilize water treadmill training as a means of specific supplementary training. The benefits of which would include, reduced re-injury risk with no negative impact on running mechanics or submaximal physiological capability.

CONCLUSION

The results of this case study suggest that 28 days of water treadmill running immersed to the anterior superior iliac, improved physiological response to sub-maximal exercise. As such, water treadmill running is a worthwhile alternative to land based running during periods of injury where impact forces inhibit rehabilitation.

PRACTICAL APPLICATION

This work supports the use of ATM as a rehabilitative training method while maintaining cardiovascular fitness during periods of injury where normal land based running is not possible. Additional supplementary use in non-injured athletes may also benefit improvements in spatio-temporal parameters and running efficiency without increased injury risk typically associated with increased training load. This latter aspect requires further investigation.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Case Report

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Myositis Ossificans in the Lumbar Spine: A Case Report

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ABSTRACT

Objective: Relatively rare case.

Background: Myositis ossificans is a benign condition which appears as a heterotopic, well-defined bone formation in muscles and soft tissues. It is most common in children and young athletes. Most myositis ossificans occur in the large muscles of proximal extremities such as the quadriceps and brachialis and it is rare to occur in the lumbar spine.

Case Report: We present a case of a 12 year-old Japanese boy with severe lower back pain. On physical examination, a severe tenderness and swelling was present in the left lumbar region, at level of L4/5. He had a traumatic history of his back. He hit nunchak (one of tools of Chinese martial arts) on the back when he was practicing it at school three months ago.

Both lumbar radiograph and lumbar Computed Tomography (CT) examination showed a ring like osteoblastic lesion calcification around left facet joint of L4/5 suggestive of myositis ossificans. He received conservative treatment. His back pain and swelling disappeared in 2 months. Follow up lumbar CT examination 8 months later showed the osteoblastic lesion calcification was more prominent than the one in the previous CT. Soft tissue swelling around the osteoblastic calcific area was not detected.

Conclusion: This case was unusual location for myositis ossificans. Careful correlation of the clinical and radiological findings is necessary to avoid surgical treatment.

KEYWORDS: Myositis ossificans; Computed Tomography (CT); Lumbar spine.

ABBREVIATIONS: CT: Computed Tomography; MRI: Magnetic Resonance Imaging; STIR: Short TI Inversion Recovery.

INTRODUCTION

Myositis ossificans is a benign condition which appears as a heterotopic, well-defined bone formation in muscles and soft tissues, typically involving muscles, tendons, ligaments, fascia, and aponeurosis.¹ It is usually found in children and young athletes. Although the exact etiology remains unclear, it is most commonly reported after major traumatic events, and to larger muscle groups.² We present a rare case of myositis ossificans in the lumbar spine.

CASE REPORT

A 12 year-old Japanese boy with severe low back pain was hospitalized to our hospital. He was 157 cm tall and 45 kg weight and had no history of sports activities. This low back pain had been restricting his motion more than one month. He had a history of trauma three months ago: he used one of Chinese martial arts at school and practiced nunchak (one of tools of Chinese martial arts). He hit the nunchak on his back. After that, his lower back gradually swollen up and the lower back pain developed afterwards in 2 months. On physical examination, a severe tenderness and swelling was present in the left lumbar region, at level of L4/5. There was no erythema. The laboratory findings were normal. Neurological examina-

tion revealed no motor or sensory deficits, with normal reflexes. Both lumbar radiographs and lumbar Computed Tomography (CT) showed a ring like calcification adjacent to left facet joint of L4/5 (Figures 1 and 2). There was no evidence of bone fracture in the lumbar spine. Lumbar Magnetic Resonance Imaging (MRI) showed high signal intensity area along the left multifidus muscle on T2-weighted axial image (Figure 3A). Short TI Inversion Recovery (STIR) sagittal image showed bone marrow edema at left lamina of L4/5 was demonstrated (Figure 3B). Faint low signal component suggestive of calcification was visualized around the left face joint of L4/5 (Figures 4A and 4B). There was no nerve root signal abnormality. Both clinical and radiological findings were compatible with myositis ossificans. He received conservative treatment. His back pain and swelling disappeared in 2 months. Follow up lumbar CT 8 months later showed calci-

fication became dense as compared to the one in the previous CT (Figure 4). Soft tissue swelling along the left multifidus muscle was improved.

DISCUSSION

Most myositis ossificans occur in the large muscles of proximal extremities such as the quadriceps and brachialis. It is rare to occur in the lumbar spine. As long as I surveyed, only 3 cases of myositis ossificans in lumbar spine were found on PubMed line.²⁻⁴ Interestingly, all of the 3 cases had no traumatic history like our case. It could be because the muscle contusion by playing sports might be rarer in the spine than in the extremities. In a small number of cases, possible etiologies include infections, burns, neuro-muscular disorders, hemophilia (factor-IX



Figure 1: Lumbar radiograph of the patient. Oblique view of lumbar radiograph shows a ring like calcification at level of L4/5 facet joint (arrow).

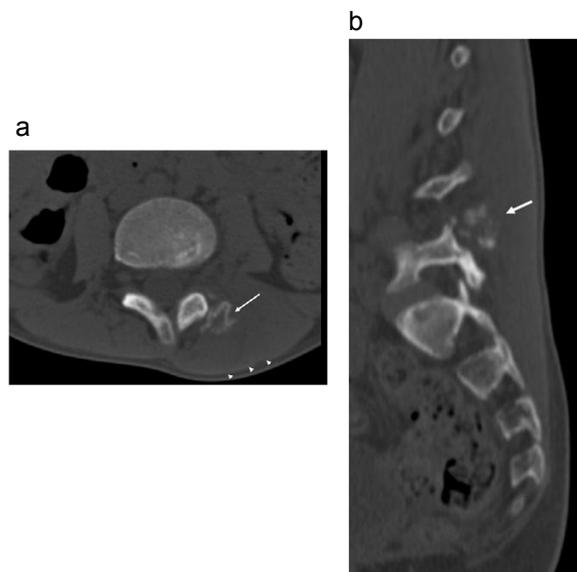


Figure 2: Lumbar CT of the patient. a. MPR sagittal image shows faint calcification around facet joint at level of L5 (arrow). b. Axial image shows a ring shape calcification. The left multifidus muscle is swollen.



Figure 3: Lumbar MRI of the patient.

a. T2-weighted sagittal image shows high signal intensity area along the left multifidus muscle (arrowheads). Faint low signal intensity structure consisted with calcification is demonstrated around left facet joint of L4-5 (arrow).

b. STIR sagittal image shows focal bone marrow edema in the left lamina of L5 (white arrow). The calcific area forms a low signal intensity ring (black arrow). Left multifidus muscle shows high signal intensity suggestive of inflammatory change.



Figure 4: Lumbar CT 8 months later

a. MPR sagittal image. The calcification is more clearly demonstrated as compared to the initial CT examination (arrow).

b. Axial image shows more mature calcification at left vertebral arch (arrow).

deficiency), tetanus, and drug abuse.⁵ We should also consider myositis ossificans if we find these etiologies.

Jacobsen S⁶ reported from his animal experiments that connective tissue injury of muscle gives stimulation to both fibroblasts and osteoblasts and these cells deposit and structure osteoid centripetally in the lesion. As the lesion matures, cancellous bone develops into mature, lamellar bone in the periphery of the lesion.³ In addition, repetitive minor mechanical injuries, ischemia or inflammation have been implicated as possible causative factors.

In our case, calcification became denser in the follow-up CT, which is suggestive of mature bone. This change is typical for myositis ossificans.

Myositis ossificans is a benign, self-limiting disease. Treatment in most cases is conservative; rest, ice, and anti-inflammatory drugs to relieve pain. Typically, a regression of the symptoms is seen in the course of disease (30%).⁷ Surgical intervention is recommended when the heterotopic bone has matured like our case. The optimum time for a surgery excision is between 9 and 12 month after the trauma.⁸

CONCLUSION

This case is the rare localization for a myositis ossificans. It was typical findings on CT examination that heterotopic bone had matured.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONSENT

The patient parents has provided written permission for publication of the case details.

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Research

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Changes of Bone Metabolism Markers and Muscular Performance with Combined Aerobic Dance Exercise and Honey Supplementation in Adult Women

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ABSTRACT

OBJECTIVE: This study investigated the effects of combined aerobic dance exercise and honey supplementation on blood bone metabolism markers and muscular power in adult women.

METHODS: Forty-four healthy sedentary women (25-40 year-old) were age and weight matched, and subsequently being assigned into four groups with n=11 per group: Control (C), honey supplementation (H), aerobic dance exercise (Ex) and combined aerobic dance exercise with honey supplementation (HEX) groups. Aerobic dance exercise was carried out for one hour per session, three times per week for eight weeks. Blood samples were taken to determine the concentrations of serum total calcium, osteocalcin (bone formation marker), serum C-terminal telopeptide of type 1 collagen (1CTP) (bone resorption marker), and parathyroid hormone (PTH). Meanwhile, subjects' lower limb muscular power was measured.

RESULTS: At the end of 8-weeks of experimental period, serum 1CTP concentration was significant greater in post-test than pre-test in Ex group. The percentage increment in 1CTP was the highest in Ex group. Meanwhile, the percentages of increment in 1CTP and PTH concentrations in HEx group were the lowest compared to the other experimental groups. Regarding muscular performance, Ex and HEx exhibited more discernable beneficial effects on lower limb average power compared to the H and C groups.

CONCLUSION: Combination of aerobic dance exercise and honey supplementation has potential to reduce the increment in bone resorption resulting from exercise, and this combination could enhance lower limb muscular power in sedentary women.

KEYWORDS: Aerobic dance; Honey supplementation; Bone metabolism; Muscular power; Women.

INTRODUCTION

Osteoporosis is a disease characterized by a loss of bone mass and the structure deterioration of bone tissue, resulting in bone fragility and an increase in susceptibility to fractures. This disease imposes major burden on the health economy and being recognized as one of the major public health problems worldwide. To date, many strategies have been developed with the aim of preventing bone loss. These include involvement in physical activity programs¹⁻⁴ and through adequate nutritional intake.⁵⁻⁹

Bone is a dynamic tissue that serves both mechanical and metabolic functions. It is in a continuous dynamic remodeling process: maintaining a tightly coupled balance between

resorption of old bone and formation of new bone.^{10,11} The balance between bone resorption and formation is influenced by age and level of strain on the bone generated by muscle contraction during movements. It is generally known that specific biochemical markers of bone turnover allows for an estimate of bone metabolic process and they have been established as useful parameters in assessing changes in bone turnover.¹²⁻¹⁵

Mechanical strain generated by exercise constitutes one of the most important stimuli to bone formation,¹⁶⁻¹⁸ and it has been suggested that weight-bearing exercises such as walking, running, dancing, and jumping are particularly necessary to help develop and maintain strong bones.¹⁹⁻²² It is known that bone tissue responds better to dynamic loading rather than static loading.^{1,23,24} According to Khan et al²⁵ and Matthews et al²⁶, dance may provide an ideal osteogenic stimulus due to its various stepping, jumping, leg lifting and landing movements which elicit unusual and moderate to high impact dynamic loads on the skeleton. These loads are experienced by an individual primarily in the lower limbs, and the upper limbs may serve as a quasi-control site.

In general, muscle contraction forces act directly or indirectly on bone and are responsible for overloading bone tissue to produce an osteogenic stimulus. It was estimated that

more than 70% of the bending moment on a bone is transmitted by muscle force rather than by body weight, supporting the idea that muscle strength places greater loads on bones than do gravitational forces associated with weight.²⁷ It is believed that the strong forces generated by the muscle contraction which impose on bone tissue during the performance of an exercise or training can increase bone metabolism and promote osteogenesis.¹ Therefore, it is speculated that strong muscle can generate high force which subsequently enable to produce strong bone, and there is a close relationship between muscular performance, bone metabolism and exercise.

Besides regular weight-bearing exercise, nutrition also plays an important role in enhancing and maintaining bone health. Honey contains carbohydrates such as glucose, fructose, sucrose and raffinose, enzymes, flavonoids, antioxidants, minerals, organic acids, proteins, phenolic acids, and vitamins such as vitamin C and vitamin E.²⁸ Some of these components are believed to be important for enhancing bone health. The nutritional fact of honey is illustrated in Table 1.²⁹

Honey has been reported to have the potential to boost calcium absorption and increase bone mineral density in rats,^{30,31} implying that honey may elicit beneficial effects on bone in animals. Since the combined effect of honey and exercise in

Ingredient		Amount in 100 g
Carbohydrates	kcal	300
Proteins	g	0.5
Fats	g	0
Minerals	mg	
Sodium (Na)		1.6-17
Calcium (Ca)		3-31
Potassium (K)		40-3500
Magnesium (Mg)		0.7-13
Phosphorus (P)		2-15
Zinc (Zn)		0.05-2
Copper (Cu)		0.02-0.6
Iron (Fe)		0.03-4
Manganese (Mn)		0.02-2
Chromium (Cr)		0.01-0.3
Selenium (Se)		0.002-0.01
Vitamins	mg	
Phyllochinon (K)		0.025
Thiamin (B ₁)		0.00-0.01
Riboflavin (B ₂)		0.01-0.02
Niacin ² (B ₃)		0.10-0.20
Panthenic acid (B ₅)		0.02-0.11
Pyridoxin (B ₆)		0.01-0.32
Folic acid (B ₉)		0.01-0.7
Ascorbic acid (C)		2.2-2.5

Adapted from Bogdanov et al.²⁹

Table 1: Nutrition fact of honey.

animal has not been confirmed, thus the present research team has conducted a study to investigate the effect of this combination on bone in rats. Interestingly, we found that there were beneficial bone effects elicited by combined jumping exercise and honey supplementation on bone mineral density, geometry, mechanical properties, and bone metabolism in female rats.³²⁻³⁴ As an extension work of the above mentioned animal study, in a recent human study carried out by the present research team, it was found that 6 weeks of combined aerobic dance exercise and honey drink supplementation elicited more beneficial effects on bone health by increasing blood bone formation marker in 19 to 29 years old young females compared to honey supplementation alone or exercise alone.³⁵

This recent study indicated that six weeks of aerobic dance exercise at three times per week, one hour per session combined with daily consumption of 20 g of honey diluted in 300 ml of plain water, may enhance bone health in the young female subjects. It was speculated that bone response varies with age, thus bone metabolism may be different in older population compared to young females with the combination of exercise and honey supplementation. Therefore the present study was proposed for determining the effectiveness of combination of aerobic dance exercise and honey supplementation on bone metabolism markers and muscular performance in adult women with age ranging from 25 to 40 years old. It is hoped that results of the present study can be used for developing age-specific exercise and nutritional programs, by formulating guidelines for the maintenance of bone health in adult female population.

MATERIALS AND METHODS

Participants

Forty-four physically healthy sedentary adult female subjects, age between 25 to 40 years old from Kelantan region, Malaysia were recruited in the present study. The inclusion criteria of the subjects were: No health problems, non-smoker, not habitual consumer of honey daily, did not engage in any training program and did not exercise more than once per week. They were required to answer questionnaires to ensure their eligibility. Subjects were matched in age, body mass, height and percent of body fat before they were randomly assigned into the experimental groups.

All participants were fully informed by the researcher about the nature of the experiments, purpose of the study, procedures, benefits, risks of feeling discomforts experienced in this present study before giving their written and signed formal consent. The present study was approved by the Human Research Ethics Committee of Universiti Sains Malaysia. During the experimental period, the participants were provided checklists, and they were required to record their participation and honey consumption rates in the checklists for ensuring their compliance and commitment to the present study.

Experimental design

Subjects' grouping: The participants were divided into four groups with 11 participants per group (n=11): 8 weeks of sedentary without supplementation control (C), 8 weeks of aerobic dance exercise (Ex), 8 weeks of honey supplementation (H), and 8 weeks of combined aerobic dance exercise and honey supplementation (HEx) groups. Participants in the control group (C) did not perform exercises nor taking honey supplementation. Meanwhile, participants in aerobic dance exercise group (Ex) performed one hour aerobic dance exercise per session, 3 times per week for 8 weeks. Participants of honey group (H) consumed honey drink for 7 days per week for a total of 8 weeks duration. Participants in combined aerobic dance exercise with honey supplementation group (HEx) performed aerobic dance exercises one hour per session, 3 times per week for 8 weeks and consumed honey drink 7 days/week for 8 week with dosage same as honey group (H). The participants in HEx group were required to consume honey drink 30 minutes before performing aerobic dance exercise on the exercised days.

Blood sample taking: Before and after the 8 weeks of exercise/supplementation/combined/ sedentary without supplementation periods, participants were seated and 8 ml of venous blood sample was taken from an antecubital vein after an 8 hours overnight fast. Drinking plain water was allowed during the fasting period. The blood was withdrawn by the laboratory technologist in the Sport Science Laboratory, Universiti Sains Malaysia to determine the concentrations of bone metabolism markers. Blood taking sessions for subjects in Ex and HEx in post-test were carried out at 8.30 the next morning after performing aerobic dance exercise, i.e. 14 hours post exercise. Serum from the clotted blood in the plain tube was used for determining serum bone metabolism markers. Serum was obtained by centrifuged the blood sample using a centrifuge (Hettich-Rotina 46RS, Germany) for 10 minutes with 4000 rpm, before being divided into equal portions and stored at -80 °C in a freezer (ThermoForma, Model 705, USA) for subsequent analysis.

Blood biochemical analysis: Serum total calcium was analyzed calorimetrically using an automatic analyzer (Hitachi Automatic Analyzer 912, Bohringer Mannheim, Germany) with commercially available reagent kits (Randox, UK). Serum osteocalcin, a bone formation marker, was analyzed using a commercially available enzyme immunological test kit (N-MID® Osteocalcin ELISA, UK), and the concentration was determined using a photometric microplate reader (Molecular Devices; Versamax tubable microplate reader, USA). Serum C-terminal telopeptide of type 1 collagen (1CTP), a bone resorption marker, was analyzed by a quantitative enzyme immunoassay kit (Orion Diagnostica UniQ 1CTP EIA, Finland), and the concentration was determined by a photometric microplate reader (Molecular Devices; Versamax tubable microplate reader, USA) Serum parathyroid hormone (PTH) was analyzed by using electrochemiluminescence immunoassay kit (ECLIA,

Mannheim, Germany) and an analyzer (Cobas e 411, USA).

Measurement of lower limb muscular strength and power: The participants were allowed to have light meals before performing muscular strength and power test for right and left lower limbs. Participants' muscular peak torque (indicator of strength) and power of both lower limbs were measured by using isokinetic dynamometer (Biodex System 3 Pro, New York, USA). In the present study, $180^{\circ}.\text{sec}^{-1}$ and $300^{\circ}.\text{sec}^{-1}$ angular velocities for knee flexion and extension were used to evaluate the status of muscular strength and power of the subjects prior and post 8 weeks of experimental period. Before testing, each participant was required to do a standard quadriceps and hamstring stretching exercises to prevent injuries. Then, the participants were familiarized with the use of the dynamometer and testing procedures to reduce the possible influences of test habituation on muscular performance. They were asked to do 5 repetitions for the $180^{\circ}.\text{sec}^{-1}$ angular velocity, and 10 repetitions for the $300^{\circ}.\text{sec}^{-1}$ angular velocity for each lower limb. Sixty seconds of rest was given to the subjects between each angular velocity.

Aerobic dance exercise program: The participants of aerobic dance exercise group (Ex) and combined honey supplementation with aerobic dance exercise group (HEx) were required to attend aerobic dance classes for 3 sessions per week, one hour per session (from 5.30pm to 6.30pm) for 8 weeks. The one hour session started with 10-15 minutes of warming up period and ended with 5-7 minutes of cooling down activities. The activities prescribed in the present aerobic dance exercise program involved continuous, controlled movement of legs and trunk, and intermittent movement of arms. The movements involved were such as side stepping, fast walking, forward and backward stepping, stepping up and down a step board, leg lifts, placing foot to the front, side and behind, knee bends, forward and side-lunging, heel rises and jumping. The intensity of aerobic dance exercise was estimated by using heart rate monitor (polar watch, S710, USA) wore by subjects throughout the dancing sessions. Besides, the subjects were given pre-recorded CD containing aerobic dance workout, and they were required to follow the workout in the CD given at home if they missed any of the aerobic dance sessions.

Honey supplementation: Honey drink was consumed by the participants in the honey (H) group, and combined aerobic dance exercise and honey supplementation (HEx) group in a dose of 20 g of honey^{36,37} diluted in 300 ml of plain water,³⁸ for 7 days per week for a total of 8 weeks duration. Gelam honey, which is a local Malaysian honey contributed by Federal Agriculture Marketing Authority, Malaysia was used in this study. In the combined aerobic dance exercise and honey supplementation (HEx) group, the subjects were required to consume honey drink 30 minutes before performing aerobic dance exercise on the exercised days.

Statistical Analysis

Statistical analysis was done by using Statistical

Package for Social Science (SPSS) version 18.0. Mean and standard deviation (SD) of the experimental data was calculated, and data was reported as mean \pm SD. Repeated measure analysis of variance (ANOVA) was performed to determine the significance of the differences within and between groups. Difference was considered significant at $p<0.05$. Confounding variables such as subjects' age, body mass, height and body fat were considered before the commencement of the study. The participants were matched in age, body mass, body height and body fat before they were randomly assigned into the experimental groups. One-way analysis of variance (ANOVA) was performed to ensure that there were no significant differences in the aforementioned confounding variables among the groups at the beginning of the study.

RESULTS

A total of forty healthy sedentary adult women (mean age 29.7 ± 5.3 years) completed the present study. Two participants from honey supplementation group (H) and two participants from combined aerobic dance exercise with honey supplementation group (HEx) were unable to continue the program due to pregnancy and personal reason during the experimental period. Participants' mean body height in C, H, Ex and HEx was 154.2 ± 5.6 cm, 153.8 ± 4.8 cm, 154.6 ± 6.1 cm, and 156.4 ± 6.0 cm respectively. The mean body weight and percentage of body fat of the subjects were 56.0 ± 9.9 kg and $32.5\pm 9.8\%$ in C group, 54.5 ± 7.8 kg and $33.0\pm 7.2\%$ in H group, 55.3 ± 5.0 kg and $32.7\pm 5.0\%$ in Ex group, and 53.4 ± 7.7 kg and $30.0\pm 7.4\%$ in HEx group respectively. There were no significant differences ($p>0.05$) between groups in means age, body height, body weight and percentage body fat at the beginning of the experimental period. The participants' mean heart rates recorded during exercise were ranging from 120 to 140 beats/min⁻¹.

The study results showed that there was statistically significant greater post-test value of serum total calcium than pre-test value in H group (Table 2). The percentage increment in osteocalcin, a bone formation marker in Ex group was the highest (+19.85%) compared to the other experimental groups (Table 2). Serum ICTP concentration was significant greater in post-test than pre-test in Ex group. The percentage increment of serum ICTP concentration was the highest (+40.51%) in Ex group, and the percentage increment of this parameter was the lowest (+14.75%) in HEx group among all the experimental groups (Table 2). The present study results also exhibited that the percentage increment of PTH hormone concentration was the lowest in HEx group among all the groups (Table 2).

Results of participants' right and left leg muscular peak torque and average power in HEx, Ex, H and C groups are illustrated in Table 3, 4, 5 and 6. In HEx group, out of 16 measured muscular performance parameters, 11 parameters showed significantly ($p<0.05$) increases, and the increases were in right knee extension peak torque at $180^{\circ}.\text{sec}^{-1}$, right knee extension average power at $180^{\circ}.\text{sec}^{-1}$, right knee flexion average power at $180^{\circ}.\text{sec}^{-1}$, right knee extension peak torque at $300^{\circ}.$

Groups	Serum total calcium concentration (mmo/L) (Mean ± SD)			Percent difference compared to pre-test (%)	Serum parathyroid hormone (PTH) concentration (pmol/L) (Mean ± SD)			Percent difference compared to pre-test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test		Pre Test	Post Test	Mean difference between pre- and post-test	
Control (C)	2.32±0.09	2.35±0.05	0.03±0.08	1.29	3.18±0.88	3.86±0.64*	0.68±0.80	21.38
Honey (H)	2.30±0.05	2.40±0.11*	0.10±0.10	4.35	3.96±0.76	4.42±1.62	0.45±1.33	11.36
Exercise (Ex)	2.38±0.18	2.34±0.10	-0.05±0.14	-2.10	3.92±1.03	4.53±1.16	0.61±1.00	15.56
Combined (HEX)	2.29±0.14	2.33±0.07	0.04±0.11	1.75	3.76±1.45	3.91±1.44	0.15±1.20	3.99
Groups	Serum osteocalcin (µg/mL) (Mean ± SD)			Percent difference compared to pre-test (%)	Serum 1CTP concentration (µg/ml) (Mean ± SD)			Percent difference compared to pre-test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test		Pre Test	Post Test	Mean difference between pre- and post-test	
Control (C)	13.11±4.80	11.43±4.86	-1.68±2.92	-12.81	2.33±0.93	3.05±1.30	0.73±1.19	30.90
Honey (H)	10.51±4.69	11.44±2.94	0.94±3.91	8.85	2.60±0.92	3.10±1.25	0.50±1.12	19.23
Exercise (Ex)	9.22±3.28	11.05±5.25	1.83±5.28	19.85	1.95±0.85	2.74±1.06*	0.79±1.06	40.51
Combined (HEX)	10.53±3.33	10.65±3.18	0.12±4.42	1.14	2.44±0.94	2.80±1.07	0.36±1.17	14.75

*p<0.05 significantly different from pre test.

Table 2: Mean of serum total calcium, serum parathyroid hormone (PTH), serum osteocalcin, and serum 1CTP concentrations.

Groups	Right knee extension peak torque at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre-test (%)	Right knee extension average power at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre-test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	77.11±10.65	79.46±11.42	2.35±7.68	3.05	129.83±20.97	136.52±5.33	6.69±14.70	5.15
Honey (H)	73.49±10.71	78.06±11.81*	4.57±4.44	6.22	123.83±21.00	134.28±25.25*	10.44±11.88	8.44
Exercise (Ex)	77.60±7.44	81.18±9.30*	3.58±4.00	4.61	135.75±15.37	144.82±21.16*	9.07±9.34	6.68
Combined (HEX)	72.86±14.55	82.41±16.58*	9.56±7.07	13.11	126.27±31.46	141.49±33.01*	15.22±17.59	12.05
Groups	Left knee extension peak torque at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre-test (%)	Left knee extension average power at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre-test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	78.66±10.26	78.72±12.86	0.05±5.17	0.08	128.96±19.64	136.91±23.52	7.95±12.44	6.16
Honey (H)	74.16±8.76	77.08±9.16	2.92±4.36	3.94	133.33±18.69	133.81±12.75	0.48±10.03	0.36
Exercise (Ex)	79.47±8.46	82.92±12.68	3.45±5.95	4.34	140.04±18.03	147.62±19.59*	7.58±8.89	5.41
Combined (HEX)	75.31±15.29	83.26±13.42**	7.94±4.95	10.56	132.62±33.47	144.41±32.28*	11.79±11.78	8.89

*p<0.05 significantly different from pre test.

**p<0.01 significantly different from pre test.

Table 3: Right and left knee extension peak torque and average power at 180°.sec⁻¹.

Groups	Right knee flexion Peak torque at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)	Right knee flexion Average power at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	47.87±14.44	49.97±7.83	2.10±12.27	4.39	72.32±21.37	76.88±18.11	4.56±11.23	6.31
Honey (H)	39.79±6.96	41.76±9.13	1.97±6.11	4.95	63.38±10.34	66.51±15.64	3.13±8.89	4.94
Exercise (Ex)	46.72±7.77	44.14±9.43	-2.58±8.99	-5.52	70.06±16.89	75.98±16.27*	5.92±6.75	8.45
Combined (HEX)	48.92±12.50	52.10±11.81	3.18±5.40	6.50	78.91±18.75	83.21±15.49*	4.30±4.95	5.45
Groups	Left knee flexion Peak torque at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)	Left knee flexion Average power at 180°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	45.46±10.37	45.92±11.53	0.46±9.73	1.01	66.36±17.34	70.66±17.97	4.29±8.88	6.46
Honey (H)	45.69±10.55	41.62±7.09	-4.07±8.33	-8.91	60.58±10.76	58.57±8.20	-2.01±7.08	-3.32
Exercise (Ex)	50.85±11.30	47.52±8.56	-3.33±13.02	-6.55	63.34±15.19	70.59±11.27	7.25±11.50	11.45
Combined (HEX)	45.38±11.63	50.82±9.99	5.44±7.67	11.98	73.80±17.66	82.97±16.29**	9.17±6.40	12.43

*p<0.05 significantly different from pre test.

**p<0.01 significantly different from pre test.

Table 4: Right and left knee flexion peak torque and average power at 180°.sec⁻¹.

Groups	Right knee extension Peak torque at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)	Right knee extension Average power at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	64.56±8.92	67.61±12.24	3.05±9.04	4.72	139.98±19.01	139.06±15.98	-0.92±13.87	-0.66
Honey (H)	59.01±5.93	62.54±8.38	3.53±5.58	5.98	133.24±13.40	142.41±20.61*	9.17±9.85	6.88
Exercise (Ex)	67.11±9.19	66.11±6.64	-1.00±7.89	-1.49	146.42±17.14	158.86±16.75***	12.45±7.15	8.50
Combined (HEX)	63.46±11.48	73.39±15.85*	9.93±10.69	15.65	135.22±34.07	151.78±36.89*	16.56±18.70	12.25
Groups	Left knee extension Peak torque at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)	Left knee extension Average power at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	72.89±8.33	64.70±9.65*	-8.19±9.43	-11.24	141.18±16.20	141.90±32.55	0.72±18.25	0.51
Honey (H)	66.99±8.30	65.53±5.94	-1.46±8.68	-2.18	132.34±15.90	143.69±19.63**	11.34±8.02	8.57
Exercise (Ex)	69.25±8.20	72.61±10.10	3.36±8.73	4.85	147.77±18.00	161.53±20.43***	13.75±8.61	9.31
Combined (HEX)	67.42±13.64	71.73±13.65	4.31±6.86	6.39	131.86±33.02	155.56±38.08**	23.70±17.79	17.97

*p<0.05, **p<0.01, ***p<0.001 significantly different from pre test.

Table 5: Right and left knee extension peak torque and average power at 300°.sec⁻¹.

Groups	Right knee flexion Peak torque at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)	Right knee flexion Average power at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	50.11±10.27	54.23±8.93	4.12±11.22	8.22	79.46±25.28	78.35±20.99	-1.12±11.58	-1.41
Honey (H)	49.98±8.44	54.10±9.09	4.12±9.56	8.24	64.59±11.36	69.13±17.62	4.54±13.78	7.03
Exercise (Ex)	58.45±9.42	59.46±9.25	1.02±6.26	1.75	78.90±22.87	85.26±23.13*	6.36±8.16	8.06
Combined (HEx)	60.67±18.82	56.77±14.82	-3.90±8.12	-6.43	85.22±19.29	93.50±19.30*	8.28±9.59	9.72
Groups	Left knee flexion Peak torque at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)	Left knee flexion Average power at 300°.sec ⁻¹ (Mean±SD)			Percent difference compared to pre- test (%)
	Pre Test	Post Test	Mean difference between pre- and post-test (±SD)		Pre Test	Post Test	Mean difference between pre- and post-test (±SD)	
Control (C)	51.30±12.35	50.66±13.98	-0.64±14.26	-1.25	70.74±21.65	67.79±26.13	-2.95±7.89	-4.17
Honey (H)	48.27±9.13	45.71±8.83	-2.56±10.90	-5.30	60.52±8.48	62.58±11.06	2.06±9.32	3.40
Exercise (Ex)	49.61±9.01	59.83±9.43**	10.22±7.88	20.60	68.86±15.98	81.25±15.06*	12.38±14.97	17.98
Combined (HEx)	54.96±8.62	58.78±16.34	3.82±10.41	6.95	76.97±20.16	89.20±19.59*	12.23±11.81	15.89

* $p < 0.05$, ** $p < 0.01$ significantly different from pre test.

Table 6: Right and left knee flexion peak torque and average power at 300°.sec⁻¹.

sec⁻¹, right knee extension average power at 300°.sec⁻¹, right knee flexion average power at 300°.sec⁻¹, left knee extension peak torque at 180°.sec⁻¹, left knee extension average power at 180°.sec⁻¹, left knee flexion average power at 180°.sec⁻¹, left knee extension average power at 300°.sec⁻¹, and left knee flexion average power at 300°.sec⁻¹. In Ex group, out of 16 measured muscular performance parameters, 9 parameters showed significantly ($p < 0.05$) increases, and the increases were in right knee extension peak torque at 180°.sec⁻¹, right knee extension average power at 180°.sec⁻¹, left knee extension average power at 180°.sec⁻¹, right knee flexion average power at 180°.sec⁻¹, right knee extension average power at 300°.sec⁻¹, left knee extension average power at 300°.sec⁻¹, right knee flexion average power at 300°.sec⁻¹, left knee flexion peak torque at 300°.sec⁻¹, and left knee flexion average power at 300°.sec⁻¹. Meanwhile in H alone group, out of 16 measured muscular performance parameters, 4 parameters showed significantly ($p < 0.05$) increases, and the increases were in right knee extension peak torque at 180°.sec⁻¹, right knee extension average power at 180°.sec⁻¹, right knee extension average power at 300°.sec⁻¹, and left knee extension average power at 300°.sec⁻¹. In C group, with no honey supplementation and without aerobic dance exercise, none of the measured muscular performance parameter increased significantly.

DISCUSSION

In the present study, we observed that there was

significant increase in serum total calcium after 8 weeks of experimental period in H group. Serum 1CTP, a bone resorption marker was significantly higher in post-test compared to pre-test value in Ex alone group. Meanwhile, the percentages increment in serum 1CTP and parathyroid hormones (PTH) in HEx group were the lowest among all the experimental groups. In general, the present findings showed that honey supplementation alone could significantly elevate serum total calcium level, whereas aerobic dance sessions alone could significantly elevate concentration of bone resorption marker. It is interestingly to observe that combined aerobic dance exercise and honey supplementation showed its potential in reducing bone resorption induced by exercise.

Since changes in bone mineral density are expected cannot be observed in a short duration of 8 weeks, therefore the present study focused on changes in blood bone metabolism parameters, where changes in blood bone turnover markers such as serum osteocalcin as bone formation marker, and serum C-terminal telopeptide of type 1collagen (1CTP) as bone resorption marker were observed. Additionally, serum total calcium and parathyroid hormone were used to reflect bone related metabolic changes.

In the present study, the significant increase in serum total calcium after 8 weeks of study period in the honey supplementation alone group reflects that the daily honey supplementation for a duration of 8 weeks enable to increase blood

calcium level in adult women. In a previous animal study done by Ariefdjohan et al,³¹ it was evidenced that consuming honey for 2 days appeared to enhance calcium absorption efficiency in rats, nevertheless, the calcium absorption enhancing effect of honey diminished with 8 weeks of chronic feeding. The authors speculated that carbohydrates found in honey such as glucose, fructose and raffinose may enhance the absorption of calcium that translates to skeletal benefits with acute feeding. Nevertheless, the calcium absorption enhancing effect did not persist with chronic long-term feeding in growing rats in this previous study. Our observation is inconsistent with this previous animal study which indicated that early nutritional benefits may not translate to long-term effects. In fact, the present human study found that consuming honey drink for 8 weeks has potential to significantly increase serum total calcium about 4.35% compared to pre-test value, and implying that honey which contained calcium, carbohydrates and other nutritional elements (Table 1) could enhance the level of circulating calcium in the blood vessels in women. Unfortunately, the calcium absorption efficiency was not measured in the present study; therefore, further study is needed to include analysis on absorption efficiency to clarify the detail physiological mechanism of the calcium metabolism induced by honey supplementation.

In the exercise alone group in the present study, significant increase in serum ICTP was observed, and the percentage increment of ICTP was the highest among the groups. Additionally, a non-statistically significant elevation of serum osteocalcin was observed in this exercise alone group, and the percentage increment of osteocalcin of this group was the highest among the groups. This observation reflects that aerobic dance sessions which were conducted three times per week for duration of 8 weeks may have potential to enhance both bone formation and resorption, i.e. one's bone turnover.

Several previous studies have been conducted to investigate the influence of exercise on bone turnover. For instances, Welsh et al³⁹ investigated the effects of acute exercise i.e. after 30 minutes of moderate brisk treadmill walking on bone remodeling in ten healthy young men, and they found that exercise have stimulated bone resorption within 32 hours of exercise, but there was no measureable effect on bone formation after 32 hours. The authors mentioned that acute and moderate exercise has caused a stimulation of osteoclasts and triggering of bone remodeling in response to exercise. In another previous study by Thorsen, Kristoffersson, and Lorentzon,⁴⁰ it was reported that a single bout of 90 minutes moderate intensity brisk walking i.e. 50% of VO_{2max} resulted an increase in the concentration of serum ICTP at 72 hours post exercise. However, significant change in serum osteocalcin was not observed in this previous study. Meanwhile, Brahm et al⁴¹ reported that running on a treadmill with 76% of VO_{2max} followed by a maximal effort until exhaustion resulted significant increases of ICTP and osteocalcin levels during 24 hours of recovery. The authors speculated that during exercise, plasma content decreased and resulted diffusion of osteocalcin to the extravascular space. The

increased amount of osteocalcin during recovery may indicate either a stimulation of the osteoblasts activity or a rediffusion of osteocalcin from extravascular space during plasma volume expansion. In our present study, statistically significant increment in bone resorption marker was also observed in the day following exercise as these aforementioned previous studies, implying that aerobic dance exercise alone may stimulated osteoclastic activity and have triggered bone turnover. Nevertheless, further study is needed to confirm the effects of exercise on bone formation marker based on the fact that merely non-statistically significant elevation of serum osteocalcin was observed in the present study.

In the combined aerobic dance exercise with honey supplementation group, the percentages increment of serum ICTP and PTH concentration were the lowest among groups. We speculated that this combination may elicit beneficial effect in reducing the increment of bone resorption induced by exercise as mentioned earlier. The findings of this present human study were slightly different from our previous animal study³⁴ which found that 8 weeks of combination jumping exercise and honey supplementation could significantly reduce the bone resorption marker of ICTP in rats. The inconsistent results between this previous animal study and the present study may indicate that animals and humans may respond differently in serum bone metabolism markers.

It was speculated that consumption of honey may increase calcium availability in the blood as evidenced in the honey supplementation alone group of this present study, and high volume of blood would be delivered to the working muscles when the participants performed aerobic dance exercise. Thus, the enhancement of calcium level in the peripheral blood due to honey drink ingestion and involvement in aerobic dance exercise may have caused reduction in bone resorption which can be reflected by ICTP level, and PTH hormone level which reflects mobilization of calcium from the bone as observed in the present study. Furthermore, according to Ososki and Kennelly,⁴² phenolic compounds in plants which are termed as phytoestrogens can possess estrogenic activity, and it is present in honey.^{32,43,44} The rise in estrogen levels at menarche in girls has been reported to be associated with a large reduction in bone turnover markers, and the effect of estrogen on bone remodeling is to decrease activation frequency and subsequent decrease the numbers of osteoclasts and osteoblasts.⁴⁵ The above mentioned phenomenon can be the reason which caused the combined effects of honey on bone turnover markers in the present study.

Regarding effects of combined exercise and nutritional supplementation, Evans et al⁴⁶ has investigated the combination effects of soy and exercise in postmenopausal women. They found that dietary supplementation with soy decreased bone resorption and formation, whereas moderate intensity endurance exercise training did not alter bone resorption, and there were no apparent additive or synergistic effects of soy and exercise on markers of bone turnover. The absence of beneficial effects

of combined nutritional supplementation and exercise in their study when compared to the present findings could be due to differences in the type of nutritional supplementation and exercise prescribed, and the age of the subjects recruited.

Recently, the present research group has conducted two combined nutritional supplementation and exercise studies in young population. Ooi et al³⁵ found that 6 weeks of aerobic dance exercise combined with honey supplementation elicited additional effects in increasing bone formation marker concentration in 19 to 28 years old young females. In another study, Lau and Ooi⁴⁷ found that combined circuit training and chocolate malt drink elicited significant effect on reducing bone resorption marker in 19 to 25 years old young males. Comparison between the findings of the present study and these two previous studies showed that humans with different age may respond differently in serum metabolism markers, and responses of these markers may be dependent on the types of exercise and exercise prescribed.

One of the most notable findings in the present was that combined exercise and honey elicited the greatest beneficial effects on muscular strength (indicated by peak torque) and average power among the groups, and this combination exhibited greater beneficial effects than exercise alone in improving these two muscular performance parameters. Furthermore, discernable improvements were not observed in both muscular strength and power in honey alone group. As expected, in the control group with no honey supplementation and without aerobic dance exercise, none of the measured muscular performance parameter increased significantly. This showed that honey elicited the best effects on muscular strength and power in the participants when it was combined with aerobic dance exercise rather than consuming honey alone.

As reported in several previous studies, physical activities such as strength training,⁴⁸ resistance training,⁴⁹⁻⁵¹ endurance training,^{48,52} and aerobic dance training^{53,54} have shown their potential to increase muscular strength of the participants after interventions. As in the present study, improvement in muscular strength and power were also observed in participants in the aerobic dance group.

In a previous study carried out by Engels et al,⁵³ it was found that 10 weeks of aerobic dance training for 60 min per session at 3 days per week, with moderate intensity of 50-70% of participants maximal heart could elicit beneficial effects on participants' lower extremity muscle strength in older adults. Okura et al⁵⁴ mentioned that increase in leg muscular strength as results of aerobic exercise might be due to increases in both nerve impulse frequency i.e. action potential and synchronicity of motor unit activations. Similar physiological responses are believed may have happened as a result of aerobic dance exercise intervention in increasing leg muscular strength and power of the participants in the present study.

One of the notable finding in the present study is that

combined honey and exercise has potential to increase muscular performance compared to other experimental groups. It is generally known that carbohydrate is the main source of energy during exercise by maintaining and increasing an individual blood glucose concentration.^{55,56} It is speculated that there was increase in absorption of carbohydrates and vitamins contained in the honey into the muscles through the enhancement of blood flow caused by the rhythmic nature of dynamic loading elicited by the physical activities during aerobic dance sessions. In the presence of exogenous carbohydrate, working muscles of the participants were able to generate more energy and managed to carry out the exercise more efficiently. The above explanation can be the reason of the present observation of greater improvement of muscle force and power generation in combined exercise with honey group than other experimental groups.

CONCLUSION

In conclusion, the present study found that honey supplementation alone could significantly elevate serum total calcium level, whereas aerobic dance sessions alone could significantly elevate bone resorption. It was also found that combination of aerobic dance exercise and honey supplementation may elicit beneficial effects on reducing bone resorption induced by exercise, and enhancing muscular strength and power in sedentary women. Therefore, supplementation of honey drink with 20 g of honey diluted in 300 ml of plain water combined with 3 days per week of aerobic dance exercise has potential to be proposed for formulating guidelines in planning exercise and nutrition promotion programs for the enhancement of bone health and muscular performance in sedentary women.

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Case Report

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Iliopsoas Tendon Injury In an Adolescent: A Case Report

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ABSTRACT

Background: The Iliopsoas tendon injuries are generally considered uncommon. Especially in children and adolescents, the iliopsoas injury usually occurs in conjunction with avulsion of the lesser trochanter. We reported a rare case of a partial tear of the left psoas major tendon in an adolescent patient.

Case Report: A 14-year-old-male who had a left inguinal pain came to our hospital for consultation. The injury occurred earlier when he was playing a basketball game he turned on a pivot and he suddenly felt left inguinal pain. As a result of the sudden pain caused by the movement he could not move his left hip joint by himself. Neurological examination revealed no motor or sensory deficits with normal reflexes. On the MRI, the left psoas major tendon showed up as swollen and was separated from the left iliacus tendon when compared to the right side. The left psoas major tendon and myotendinous junction showed high signal intensity suggestive of a partial tear on STIR axial image. The lesser trochanter showed slightly high signal intensity when compared to the opposite side but showed no evidence of an avulsion fracture.

Conclusion: The Iliopsoas tendon injuries without lesser trochanteric avulsion in children and adolescents are distinctly uncommon. There is an estimated prevalence of 0.66%. In future we would suggest, we need to evaluate both the lesser trochanter and the insertion of the iliopsoas tendon to rule out lesser trochanter avulsion on the MRI.

KEYWORDS: Iliopsoas muscle; Lesser trochanter; Magnetic Resonance Imaging (MRI).

INTRODUCTION

The iliopsoas tendon acts a thigh flexor and aids in lateral rotation of the hip. The Iliopsoas injuries are generally considered uncommon. Especially, in children and adolescents, the Iliopsoas injury usually occurs in conjunction with avulsion of the lesser trochanter.¹ We report a rare case of a partial tear of the left psoas major tendon in an adolescent patient. The authors obtain written informed consent from the patient for submission of this manuscript for publication.

CASE REPORT

A 14-year-old-male who had a left inguinal pain came to our hospital for consultation. The injury occurred when he was earlier playing a basketball game and turned on a pivot, he suddenly felt left inguinal pain. He is 170 cm tall; 50 kg in weight and has no history of trauma or disease. He has been playing basketball for 5 years at school and plays it for 4 hours every day. On physical examination, there was severe tenderness present in the left inguinal region. Also, there was no erythema. He could not move his left hip joint by himself. Neurological examination revealed no motor or sensory deficits with normal reflexes. The laboratory findings were normal. Hip radiograph showed no abnormality (Figure 1). On MRI, the left psoas major

tendon showed up as swollen and was separated from the left iliacus tendon on STIR axial image when compared to the right side (Figure 2). It shows high signal intensity in that area suggestive of hematoma, this is shown between the psoas major muscle and iliacus muscle (Figures 2 and 3). The left psoas major tendon and myotendinous junction showed high signal intensity on STIR coronal image (Figures 3 and 4). In addition, a partial tear of the left psoas major tendon was visualized (Figures 3 and 4). However, the left lesser trochanter and insertion of the left iliopsoas tendon was maintained (Figure 5). The lesser trochanter showed slightly high signal intensity as compared to the opposite side but showed no evidence of avulsion fracture on STIR axial image (Figure 5).



Figure 1: Antero-posterior view of Hip radiograph. There is no evidence of bone fracture in the left lesser trochanter (arrows).



Figure 2: STIR axial hips MRI at level of acetabulums. As compared to the right iliopsoas tendon (white circle), the left psoas major tendon (white arrow) showed swollen and was separated from the left iliacus tendon (black arrow). High signal intensity area suggestive of hematoma is visualized mainly around the left psoas major muscle.



Figure 3: STIR coronal hips MRI at level of pubic symphysis. Both the left psoas major tendon (white arrow) and myotendinous junction (arrowheads) show partial high signal intensity suggestive of tear. The right psoas major tendon (asterisk) is normal.



Figure 4: STIR coronal hips MRI at level of pubic symphysis at level of the 4 mm behind from Figure 3. The partial tear of the left psoas major tendon is visualized (white arrow). High signal intensity hematoma is along the left psoas major tendon.

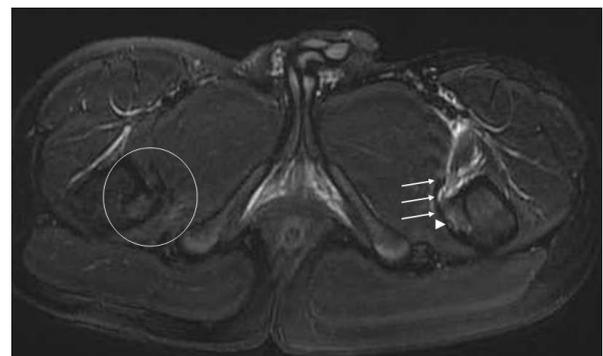


Figure 5: STIR axial hips MRI at level of both lesser trochanters. Both the left lesser trochanter (arrowhead) shows faint high signal intensity but shows no avulsion fracture. The insertion of the iliopsoas tendon (arrow) is the same signal and form as the right side (white circle).

We diagnosed a partial tear of the left psoas major myotendinous junction and tendon due to overuse. He was hospitalized and underwent a conservative therapy. He was discharged after a week with no inguinal pain.

DISCUSSION

The iliopsoas muscle belongs to the inner hip and comprises of a complex of two muscles called psoas major muscle and iliacus muscle. Both muscles pass below the inguinal ligament through the muscular lacuna together and merge at their midpoint to form a common insertion at the lesser trochanter of the femur.¹⁻³ The iliopsoas muscle controls the various actions of postural changes such as walking, running, sitting, or standing. It also keeps the upper body straight while one is performing certain types of exercises in the supine position.^{1,2,4}

The iliopsoas tendon injuries without lesser trochanteric avulsion in children and adolescents are distinctly uncommon, with an estimated prevalence of 0.66%.^{1,2} An even smaller percentage of these injuries occur spontaneously. This is due to the relative weakness of the apophyses compared to the

iliopsoas tendon.^{5,6} Regarding the epiphyseal union of the lesser trochanter, Shama Y et al⁷ reported that age of epiphyseal union of the lesser trochanter was 18-19 in male and women together. Cardoso⁸ reported that the lesser trochanter at age of 14 of male showed nonunion.

In our case, the left lesser trochanter was not fractured but showed faint bone marrow edema. We think the bone marrow edema of the left lesser trochanter occurred as a result of an overload from the left iliopsoas tendon. In addition, we found a partial tear of the left psoas major tendon on MRI. It may be due to the overuse from the patient's sports activity. In adults, isolated fractures of the lesser trochanter are rare but can occur as a result of trauma or sports injuries like jumping, kicking and so on.^{3,4} When iliopsoas muscle and tendon are subjected to a load beyond the strength of the muscle, it occurs. The vast majority of ruptures are partial muscle/tendon tears.^{5,6} Our case is the same as the adults' iliopsoas muscle injuries. Taking a MRI is a good choice to evaluate iliopsoas tendon injuries and distinguishes it from other hip joints diseases. In our case, we could rule out the lesser trochanteric avulsion on MRI.

The iliopsoas muscle/tendon injuries are usually treated conservatively, with rest, physical therapy, and/or anti-inflammatory medications, often with good results.^{1,2}

CONCLUSION

Iliopsoas tendon injuries without lesser trochanter avulsion are uncommon in children and adolescents. We need to evaluate both the lesser trochanter and the insertion of the iliopsoas tendon to rule out lesser trochanter avulsion on MRI. The hips MRI is a good modality for distinguish from them.

CONFLICTS OF INTEREST: None.

CONSENT

The authors obtained written informed consent from the patient for submission of this manuscript for publication.

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