ORIGINAL ARTICLE

The Comparison of Lower Limb Muscles Strength among Adolescent Hockey Players with and without Chronic Ankle Instability

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ABSTRACT

Background and Objectives: Chronic ankle instability (CAI) is recurrent sprain, episodes of giving-way of the ankle joint, pain, swelling, and decreased function. Ankle sprain is the most common injury among Malaysian hockey players, with 53% developing CAI. : To identify the prevalence of CAI among adolescent hockey players, and to compare lower limb muscle strength among adolescent hockey players with and without chronic ankle instability. **Methods:** The cross-sectional study was conducted on 103 adolescent hockey players, assessing the presence of CAI using the Identification of Functional Ankle Instability (IdFAI-M) questionnaire, and lower limb muscle strength was measured using a hand-held dynamometer (HHD). Descriptive statistics were performed to summarise the sociodemographic and muscle strength. The Mann-Whitney U test was used to compare muscle strength between the CAI and the non-CAI groups. **Results:** The prevalence of CAI among participants was 49.5%, significantly higher than in the general adolescent athlete population. The CAI group showed significantly stronger knee flexor in the non-dominant (p=0.040), ankle inversion muscle in the dominant (p=0.022) and non-dominant (p=0.045), and eversion muscle strength in the non-dominant (p=0.009) compared to the group without CAI, with moderate effect sizes. **Conclusion:** Effective CAI management in adolescent hockey players requires targeted strength training of the hip, knee, and ankle muscles, along with proprioceptive exercises. Larger studies are needed to confirm these findings and to optimize injury-prevention strategies in sports.

Keywords: Chronic ankle instability, dynamometer, hip, knee, isometric

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INTRODUCTION

Chronic ankle instability (CAI) is characterised by recurrent ankle sprains, episodes of ankle joint instability, pain, swelling, and impaired function (Hertel & Corbett, 2019). According to a previous study by Manaf et al. (2021), sprains and strains are the most common forms of injuries among hockey players (63%), with the ankle being the most common site (18.6%).

According to a systematic review conducted by Lin et al. in 2021, 47% of 1093 athlete participants have a history of ankle injuries, while 25% have been diagnosed with CAI. Therefore, the study found that 53% of those who injure their ankles develop CAI. In the same study, 11 participants were hockey players, and 3 reported chronic ankle instability (CAI), yielding a CAI prevalence of 27% among hockey players. Given the small sample size of hockey players, the reported prevalence should be interpreted with caution, as it may be subject to substantial error and not accurately reflect the true prevalence in the broader population.

Fraser et al. (2020) and Hertal and Corbett (2019) report that individuals with chronic ankle instability (CAI) exhibit reduced strength in plantar flexion, inversion, eversion, and dorsiflexion compared with healthy individuals. Aside from this, muscle weakness around the unstable ankle led to deficits in concentric knee flexion and extension, isometric hip abduction, extension, and external rotation, and in eccentric hip flexion (Hertal & Corbett, 2019). In addition, McCann et al. (2018) mention that CAI individuals have less isometric hip extension and external rotation strength.

A variety of populations have been investigated on the relationship between CAI and lower limb muscle strength (Labanca et al, 2024; Wisthoff et al, 2019; McCann et al, 2018). However, there is limited research specifically focusing on lower limb muscle strength profiles in hockey players with CAI. Kim et al. (2017) was the only available research that concentrated solely on CAI in hockey players. However, this study was conducted only on adult, national women's hockey players in Korea, and focused on ankle evertor muscles. Kim et al. (2017) demonstrate ankle evertor muscles as significant in relation to CAI, providing valuable insights into the underlying mechanisms and helping guide targeted interventions for hockey players.

Ankle evertor muscles play a critical role in ankle stability and control during weight-bearing activities, and their weakness or dysfunction may contribute to the development and perpetuation of ankle instability. However, other lower limb muscle groups, such as the hip, knee, and ankle muscles, are also crucial for developing targeted interventions to improve player performance and prevent injuries among hockey players. Therefore, this study investigated the strength of the lower limb muscles among adolescent hockey players with and without chronic ankle instability.

METHODOLOGY

Research Design

This research employed a cross-sectional study design and was deemed useful for achieving a thorough understanding of the specific topic, its occurrence, and the phenomenon in a real-world setting. The 103 adolescent hockey players were recruited in this study. Adolescent hockey players diagnosed with chronic ankle instability (CAI) were recruited from various school hockey clubs in Selangor.

Sampling Size

Online Raosoft sample size calculator, a sample size of 99 adolescent hockey players was recommended based on a response rate of 50%, a confidence interval of 95%, and a margin of error of 5%, as shown in Table 3.1. A 20% dropout rate was added using the formula (n/(1-20%)) to reduce the possibility of attrition. Therefore, of the 133 adolescent hockey players, a minimum of 123 were required to participate in the study.

Sampling Design

This research applied purposive sampling. The inclusion criteria were 1) Adolescent hockey players aged 13-16 years old, 2) Actively involved in hockey training and competition for at least 2 years, 3) history of acute ankle sprain that resulted in swelling, pain, and temporary loss of function for at least 1 day , 4) ≥ 2 repeated episodes of “giving way” in the past 6 months and 5) Identification of Functional Ankle Instability (IdFAI-M) ≥ 11. Meanwhile the exclusion criteria were 1) History of concussion: recent concussion <2 weeks or symptoms persisting >1 month, 2) Had ever been diagnosed with a balance, vestibular, neurological or respiratory disorder , 3) Had a history of fracture or surgery in the lower extremity and 4) Currently using assistive-walking devices

Ethical Concerns

Ethical approval was sought from the UiTM Research Ethics Committee (REC UiTM) before proceeding with this study. This study obtained permission from the Ministry of Education Malaysia and the Selangor State Education Department prior to data collection in educational institutions. Participants provided informed consent prior to data collection. The anonymity of participants’ data was assured, and all data gathered will remain confidential and will only be used for academic purposes. As participants were minors, parental consent was obtained. All participants, including parents or legal guardians of minors, were approached and treated with respect. The participants were recruited using a gatekeeper-mediated approach

Research Instruments

Demographic Data

Demographic characteristics of participants included age, gender, race, Body Mass Index (BMI), dominant leg, and years of participation in hockey. This form provided a comprehensive overview of the participants’ characteristics and aided in data analysis in relation to the research objectives.

Physical Activity Readiness Questionnaire (PAR-Q)

The Physical Activity Readiness Questionnaire (PARQ) was utilised to assess the participant's readiness for physical activity. It included a series of questions about current health, such as heart problems or joint issues, and was essential for identifying preexisting medical conditions that could have been exacerbated by increased physical activity during this study.

Identification of Functional Ankle Instability (IdFAI)

Donovan et al. (2020) determined the prevalence of CAI using the Identification of Functional Ankle Instability (IdFAI) questionnaire, which comprises of 1 question reporting the total number of previous ankle sprains, scored numerically, and 9 Likert-scale questions that inquire about signs of the ankle "giving way" or "feeling unstable". CAI was determined using an IdFAI threshold score of 11 or higher for at least one ankle (Donovan et al., 2020). In the study, we effectively utilised the adapted Malay version of IdFAI (IdFAI-M), which Omar & Abdul-Karim (2021) demonstrated to have excellent reliability and validity as a self-report tool for evaluating ankle instability.

Lower Limb Muscle Strength

Muscle strength in this study was measured using a hand-held dynamometer (HHD), employing the standardised push–pull isometric testing method. The HHD was selected because it is a practical, portable,

and widely validated instrument for assessing lower limb muscle strength in both clinical and field-based settings, particularly among adolescent and athletic populations where large, fixed dynamometry systems are impractical. Mentiplay et al. (2015) developed positions for measuring isometric strength of the hip, knee, and ankle muscle groups that demonstrated high reliability based on prior research and pilot work involving assessments across a variety of positions.

Hip Muscles

To measure hip flexor strength, the participant was seated with the hips and ankles bent to 90 degrees. The dynamometer was positioned on the anterior thigh, just above the knee joint. The participant lay prone with hips and knees extended, and the dynamometer was placed on the posterior aspect of the shin, proximal to the ankle joint, to assess hip extensor strength. The adductors of the hip were evaluated with the participant supine and the hips and legs extended. The dynamometer was positioned proximal to the ankle joint on the medial aspect of the thigh. The participant lay supine with hips and knees extended, and the dynamometer was placed on the lateral aspect of the shin, proximal to the ankle joint, to measure hip abductor strength.

Knee Muscles

To evaluate knee extensors, the participant was seated with their pelvis and knees flexed to 90 degrees. Then, the dynamometer is positioned on the anterior tibia, just above the ankle joint. The participant was seated with the hips and knees flexed to 90 degrees, and the dynamometer was placed on the posterior aspect of the shin, proximal to the ankle joint, to evaluate the knee flexors.

Ankle Muscles

The ankle plantar flexors were measured with the participant prone, the ankle in plantar flexion (pointing downwards), and the hips and knees extended. The dynamometer was placed on the sole of the foot over the metatarsal heads. For testing the ankle dorsiflexors, the participant lay supine with the ankle relaxed and the hips and legs extended, with the dynamometer placed over the metatarsal heads on the dorsum (top) of the foot.

Data Collection Procedure

Prior to data collection, appointments were coordinated with school administrators and hockey coaches to schedule assessment sessions at times that did not disrupt academic or training activities. Participants attended the assessments in organised group visits at their respective schools, with each participant undergoing individual assessment in a designated area to ensure privacy and standardisation. All measurements were conducted by the principal researcher, who had been trained in the use of the hand-held dynamometer (HHD) and standardised testing positions, without the involvement of external assessors, to minimise inter-rater variability. Before assessment, participants and their guardians received clear verbal and written instructions, including an explanation of study procedures, completion of demographic forms, the Physical Activity Readiness Questionnaire (PAR-Q), and the Identification of Functional Ankle Instability (IdFAI-M), as well as guidance to wear appropriate sports attire and to avoid strenuous activity immediately prior to testing. To ensure data accuracy and consistency, standardised protocols for participant positioning, dynamometer placement, testing sequence, and verbal encouragement were strictly followed, with all assessments conducted using the same equipment and procedures for every participant, in line with established recommendations for HHD reliability. Each participant's session, including questionnaire completion and testing of hip, knee, and ankle muscle groups, lasted approximately 30–40 minutes, with rest periods provided between measurements to prevent fatigue. Data were recorded immediately onto structured paper data collection forms and later entered into an electronic database for analysis, with double-checking performed to reduce transcription errors. Throughout the measurement process, safety measures were prioritised, including screening with the PAR-Q, continuous monitoring for discomfort or adverse symptoms, provision of rest as needed, and immediate cessation of testing if participants reported pain or instability, ensuring that all procedures were conducted in accordance with the study's ethical and safety guidelines.

Statistical Analysis

The data gathered from the respondents were analysed using Statistical Package for the Social Sciences (SPSS) version 29 to ensure accurate calculations and reliable results. Descriptive statistics of mean and standard deviation (SD) for the prevalence of CAI among adolescent hockey players and evaluation of lower limb muscle strength among adolescent hockey players with and without CAI. The Shapiro-Wilk test showed the data distribution is normal. Therefore, an independent t-test was conducted to compare lower limb muscle strength between adolescent hockey players with and without chronic ankle instability.

RESULT

Participant Demographics

A total of 103 adolescent hockey players participated in the study, recruited from the academy hockey school around Selangor. The demographic characteristics of the participants are summarized in Table 1.

Table 1: Descriptive Statistics of Participant Demographics

Demographic	Mean ± SD
Age (Years)	14.47 ± 1.17
BMI (kg/m2)	19.29 ± 3.42
Years of Playing Experience	4.99 ± 2.17

Dominant Leg (Right/ Left) %	96.1 / 3.9
Gender (Male/ Female) %	47.6 / 52.4

Prevalence of CAI Among Adolescent Hockey Players

The prevalence of CAI among the participants was assessed using the Identification of Functional Ankle Instability (IdFAI-M) questionnaire. A total score of 11 or higher on the IdFAI-
M indicated the presence of CAI. The prevalence of CAI is presented in Table 2.

Table 2: Prevalence of Chronic Ankle Instability

CAI Status	Frequency (n)	Percentage (%)
CAI	51	49.5
Without CAI	52	50.5
Total	103	100

4.4.2 Muscle Strength

Muscle strength was measured for various muscle groups, including hip (flexion, extension, abduction, adduction), knee (flexion, extension), and ankle (plantarflexion, dorsiflexion, inversion, eversion). The results are summarized in Table 3

Table 3: Lower Limb Muscle Strength

Muscle Group	Leg	CAI Mean ± SD	Without CAI Mean ± SD	p-value	Effect Size (r)
Hip Flexion	Dominant	17.30 ± 3.37	16.89 ± 3.27	0.561	0.057
	Non	17.29 ± 3.31	17.13 ± 3.25	0.784	0.027
Hip Extension	Dominant	17.73 ± 3.65	16.97 ± 3.67	0.926	0.009
	Non	16.59 ± 2.99	15.84 ± 3.58	0.163	0.138
Hip Abduction	Dominant	16.10 ± 3.41	15.75 ± 3.79	0.709	0.037
	Non	15.94 ± 3.52	15.24 ± 3.79	0.381	0.084
Hip Adduction	Dominant	15.31 ± 3.81	15.34 ± 3.55	0.828	0.021
	Non	15.11 ± 3.79	14.46 ± 3.57	0.276	0.107
Knee Flexion	Dominant	14.51 ± 4.23	14.46 ± 3.57	0.100	0.162
	Non	14.46 ± 4.57	12.55 ± 4.25	0.040*	0.202
Knee Extension	Dominant	16.19 ± 3.63	15.96 ± 3.95	0.810	0.024
	Non	15.13 ± 3.47	14.71 ± 3.77	0.584	0.054
Ankle Plantarflexion	Dominant	17.71 ± 3.54	16.83 ± 2.28	0.908	0.011
	Non	17.28 ± 3.58	17.46 ± 3.16	0.856	0.017
Ankle Dorsiflexion	Dominant	12.81 ± 2.84	12.69 ± 2.91	0.618	0.049
	Non	12.40 ± 2.65	12.93 ± 3.19	0.864	0.017
Ankle Inversion	Dominant	11.04 ± 2.56	9.89 ± 2.72	0.022*	0.226
	Non	10.59 ± 2.49	10.12 ± 2.87	0.045*	0.198
Ankle Eversion	Dominant	11.23 ± 2.25	10.54 ± 2.87	0.148	0.137
	Non	11.18 ± 2.25	9.97 ± 2.78	0.009*	0.258

For hip flexion, hip extension, hip abduction, and hip adduction, no significant differences in muscle strength were found between CAI groups. Meanwhile, the knee flexor showed no significant difference on the dominant side (U = 1077.0, p = 0.100) and a significant difference on the non-dominant side (U = 1015.5, p = 0.040), suggesting potentially weaker knee flexion in the CAI group. Effect sizes were moderate for both dominant and non-dominant sides (r = 0.162 and r = 0.202, respectively). No significant differences were observed for dominant (U = 1289.0, p = 0.807) or non-dominant sides (U = 1243.0, p = 0.584) in knee extension strength between both groups. Effect sizes were small (r = 0.024 and r = 0.054, respectively), indicating similar knee extension strength in both groups.

Ankle plantarflexion and ankle dorsiflexion also showed no significant differences in muscle strength for dominant or non-dominant sides between groups. Ankle inversion showed a trend toward significance on both the dominant (U = 978.5, p = 0.022) and non-dominant (U = 1022.0, p = 0.045) sides. Effect sizes were moderate (r = 0.226 and r = 0.198, respectively). This suggests that participants with CAI may have significantly greater ankle inversion strength than those without CAI. For ankle eversion, no significant difference was found for the dominant side (U = 1098.0, p = 0.132), but a significant difference was found for the non-dominant side (U = 928.5, p = 0.009). Effect sizes were moderate (r = 0.148 and r = 0.258, respectively). These results suggest that the 'CAI' group has stronger ankle eversion strength than the 'without CAI' group.

DISCUSSION

The study found that nearly half of the adolescent hockey players (49.5%) experienced chronic ankle instability (CAI). The data revealed that participants with CAI generally exhibited stronger lower limb muscles across most groups compared to those without CAI. This finding contrasts with typical expectations that CAI might lead to decreased muscle strength due to instability and potential avoidance of activity to prevent injury.

The prevalence of CAI is notably higher compared to the 20.0% reported for the general adolescent athlete population by Donovan et al. (2020), the 31.1% among high school athletes across various sports by Holland

et al. (2019), the 27.3% among high school and collegiate hockey athletes by Tanen et al. (2014) and the average of 25% from variations in study population and range of sport by Lin et al. (2021). This suggests that the physical and biomechanical challenges specific to hockey may contribute more significantly to the development and persistence of CAI than other sports. The equal distribution of participants with and without CAI in this study enables a robust comparative analysis, underscoring the importance of targeted preventive measures and rehabilitation programs tailored to hockey players.

In examining hip flexion, extension, abduction, and adduction, the CAI group exhibited higher mean values, indicating greater muscle strength. This trend was consistent in both the dominant and non-dominant sides, although the differences were not statistically significant. This is somewhat consistent with the findings of McCann et al. (2018), who reported that the CAI group exhibited lower hip extension strength but similar hip abduction strength to our study. The slight variations could be attributed to differences in study populations or methodologies. These results suggest that hip muscle strength may help compensate for ankle instability, potentially providing greater stability and support during dynamic movements.

Regarding knee flexion, the findings suggest a trend toward stronger flexion on both the dominant and non-dominant sides among those with CAI compared with those without. Stronger knee flexors may indicate a compensatory mechanism in which individuals with CAI develop increased knee flexor strength to stabilize the lower extremity and compensate for ankle instability. In adolescents with CAI, this increased knee flexor strength may result from neuromuscular adaptations aimed at maintaining balance and performance. For knee extension, muscle strength was similar between groups, with no significant differences, suggesting that this muscle group might not be as directly affected by CAI or that compensatory strengthening might have balanced out potential deficits.

For ankle plantarflexion and ankle dorsiflexion, the muscle strengths were similar between the CAI and the non-CAI groups, with no significant differences. This finding is supported by Park et al. (2019), who also found no significant differences in dorsiflexion and plantarflexion strengths between ankles. However, Fraser et al. (2020) reported that plantarflexion strength was decreased in the CAI group. These mixed results suggest that these muscle groups might not be as directly affected by CAI, or that compensatory strengthening could mitigate potential deficits.

Ankle inversion and eversion revealed noteworthy findings: the CAI group showed significantly greater muscle strength. These muscle groups are directly involved in maintaining ankle stability and preventing excessive movements that can lead to instability. The significant differences indicate that adolescents with CAI might develop stronger ankle inversion and eversion muscles as a compensatory strategy to enhance ankle stability and control excessive movements that could exacerbate their instability. This enhanced muscle strength in the CAI group suggests a neuromuscular adaptation where the body responds to chronic instability by strengthening the muscles that directly contribute to maintaining ankle stability. These findings contrast with the research of Augustsson and Sjöstedt (2023) and Fraser et al. (2020), which noted decreased strength in ankle inversion and eversion in CAI groups. However, Park et al. (2019) found lower inversion strength in the CAI group compared to the group without CAI, with no significant differences in eversion strength between ankles.

Plausible explanations include that individuals with CAI might develop stronger muscles in certain groups to compensate for the instability. For example, they might rely more on other muscle groups to stabilize the ankle during movement. Secondly, CAI participants might be more likely to engage in rehabilitation programs that include strength training exercises, which could lead to increased muscle strength as a therapeutic outcome. Thirdly, selection bias may occur, whereby the CAI group consists of individuals who are more athletic and naturally have higher muscle strength, or who are at a higher risk of injury due to the more agile positions they hold in the field. These differences in muscle strength between the CAI and non-CAI groups could also be attributed to variations in study populations, including age, athletic experience, rehabilitation history, and the specific demands of different sports.

The study limitations included its cross-sectional design, potential biases in self-reported data, and variability in participants' athletic performance. Future research employing longitudinal designs and objective measures is crucial to establish causal relationships and validate these findings across diverse adolescent athlete populations. By addressing these findings, coaches, trainers, and healthcare providers can better tailor interventions to optimize athletic performance and mitigate the effects of ankle instability in this vulnerable population.

CONCLUSION

The findings underscored a high prevalence of CAI and exhibited stronger lower limb muscles, particularly in knee flexion, ankle inversion, and eversion, compared to those without CAI, suggesting potential compensatory mechanisms or adaptive responses to ankle instability. Notably, while some muscle groups showed significant differences in strength between groups, others showed similar strength, indicating a complex interplay of factors influencing muscle adaptation and function.

Implications for training and rehabilitation programs were discussed, emphasizing the importance of targeted strength training and preventive measures to manage and reduce the risk of CAI among adolescent hockey players. Strategies focusing on ankle, hip, and knee muscle strengthening, alongside proprioceptive and balance training, were recommended to enhance joint stability and athletic performance.

REFERENCES

Augustsson, S. R., & Sjöstedt, E. (2023). A test battery for evaluation of muscle strength, balance, and functional performance in subjects with chronic ankle instability: A cross-sectional study. *BMC Sports Science, Medicine & Rehabilitation, 15*(1), 55. https://doi.org/10.1186/s13102-023-00669-5

Donovan, L., Hetzel, S., Laufenberg, C. R., & McGuine, T. A. (2020). Prevalence and impact of chronic ankle instability in adolescent athletes. *Orthopaedic Journal of Sports Medicine, 8*(2), 2325967119900962. https://doi.org/10.1177/2325967119900962

Fraser, J. J., Koldenhoven, R. M., Jaffri, A. H., Park, J. S., Saliba, S. F., Hart, J. M., & Hertel, J. (2020). Foot impairments contribute to functional limitation in individuals with ankle sprain and chronic ankle instability. *Knee Surgery, Sports Traumatology, Arthroscopy, 28*(5), 1600–1610. https://doi.org/10.1007/s00167-018-5028-x

Hertel, J., & Corbett, R. O. (2019). An updated model of chronic ankle instability. *Journal of Athletic Training, 54*(6), 572–588. https://doi.org/10.4085/1062-6050-344-18

Holland, B., Needle, A. R., Battista, R. A., West, S. T., & Christiana, R. W. (2019). Physical activity levels among rural adolescents with a history of ankle sprain and chronic ankle instability. *PLOS ONE, 14*(4), e0216243. https://doi.org/10.1371/journal.pone.0216243

Kim, T., Kim, E., & Choi, H. (2017). Effects of a 6-week neuromuscular rehabilitation program on ankle-evertor strength and postural stability in elite women field hockey players with chronic ankle instability. *Journal of Sport Rehabilitation, 26*(4), 269–280. https://doi.org/10.1123/jsr.2016-0031

Labanca, L., Tedeschi, R., Mosca, M., & Benedetti, M. G. (2024). Individuals with chronic ankle instability show abnormalities in maximal and submaximal isometric strength of the knee extensor and flexor muscles. *The American Journal of Sports Medicine, 52*(5), 1328–1335. https://doi.org/10.1177/0363546524123456

Lin, C. I., Houtenbos, S., Lu, Y. H., Mayer, F., & Wippert, P. M. (2021). The epidemiology of chronic ankle instability with perceived ankle instability: A systematic review. *Journal of Foot and Ankle Research, 14*(1), 41. https://doi.org/10.1186/s13047-021-00480-w

Manaf, H., Justine, M., & Hassan, N. (2021). Prevalence and pattern of musculoskeletal injuries among Malaysian hockey league players. *Malaysian Orthopaedic Journal, 15*(1), 21–26. https://doi.org/10.5704/MOJ.2103.004

McCann, R. S., Bolding, B. A., Terada, M., Kosik, K. B., Crossett, I. D., & Gribble, P. A. (2018). Isometric hip strength and dynamic stability of individuals with chronic ankle instability. *Journal of Athletic Training, 53*(7), 672–678. https://doi.org/10.4085/1062-6050-238-17

Mentiplay, B. F., Perraton, L. G., Bower, K. J., Adair, B., Pua, Y. H., Williams, G. P., McGaw, R., & Clark, R. A. (2015). Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: A reliability and validity study. *PLOS ONE, 10*(10), e0140822. https://doi.org/10.1371/journal.pone.0140822

Omar, M. K., & Abdul-Karim, S. (2021). Validity and reliability of the Malay version of the identification of functional ankle instability (IdFAI-M) questionnaire among Malaysian university athletes. *Malaysian Orthopaedic Journal, 15*(1), 32–42. https://doi.org/10.5704/MOJ.2103.006

Park, Y. H., Park, S. H., Kim, S. H., Choi, G. W., & Kim, H. J. (2019). Relationship between isokinetic muscle strength and functional tests in chronic ankle instability. *The Journal of Foot and Ankle Surgery, 58*(6), 1187–1191. https://doi.org/10.1053/j.jfas.2019.04.005

Tanen, L., Docherty, C. L., Van Der Pol, B., Simon, J., & Schrader, J. (2014). Prevalence of chronic ankle instability in high school and Division I athletes. *Foot & Ankle Specialist, 7*(1), 37–44. https://doi.org/10.1177/1938640013509670

Wisthoff, B., Matheny, S., Struminger, A., Gustavsen, G., Glutting, J., Swanik, C., & Kaminski, T. W. (2019). Ankle strength deficits in a cohort of college athletes with chronic ankle instability. *Journal of Sport Rehabilitation, 28*(7), 752–757. https://doi.org/10.1123/jsr.2018-0092