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BRIEF REPORT

The Potential for a Targeted Strength-Training Program to Decrease Asymmetry and Increase Performance: A Proof of Concept in Sprinting

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The global application of horizontal force (F_H) via hip extension is related to improvements in sprint performance (eg, maximal velocity [v_{max}] and power [P_{max}]). Little is known regarding the contribution of individual leg F_H and how a difference between the legs (asymmetry) might subsequently affect sprint performance. The authors assessed a single male athlete for pre-post outcomes of a targeted hip-extension training program on F_H asymmetry and sprint-performance metrics. An instrumented nonmotorized treadmill was used to obtain individual leg and global sprint kinetics and determine the athlete's strong and weak leg, with regard to the ability to produce F_H while sprinting. Following a 6-wk control block of testing, a 6-wk targeted training program was added to the athlete's strength-training regimen, which aimed to strengthen the weak leg and improve hip-extension function during sprinting. Preintervention to postintervention, the athlete increased F_H (standardized effect [ES] = 2.2; +26%) in his weak leg, decreased the F_H asymmetry (ES = −0.64; −19%), and increased v_{max} (ES = 0.67; +2%) and P_{max} (ES = 3.2; +15%). This case study highlighted a promising link between a targeted training intervention to decrease asymmetry in F_H and subsequent improvement of sprint-performance metrics. These findings also strengthen the theoretical relationship between the contribution of individual leg F_H and global F_H while sprinting, indicating that reducing asymmetry may decrease injury risk and increase practical performance measures. This case study may stimulate further research investigating targeted training interventions in the field of strength and conditioning and injury prevention.

Keywords: Woodway nonmotorized treadmill, horizontal force, power, velocity, hip extensors

Injury prevention and athletic performance are 2 fundamental pillars central to the development of sports science. While often considered unrelated, injury and performance are inherently coupled; unfortunately, the interplay of these capacities receives minor attention as a by-product of the overwhelming focus on global performance. Consequently, limited studies exist examining this relationship and its application in the field.[1] Researchers often aim at progressing either performance or injury prevention, but not both. In a practical sense, an injured athlete simply cannot perform at the highest level. Thus, in some cases injury prevention and performance enhancement are pragmatically one in the same.

Interlimb differences, or asymmetry, are prevalent in an array of important metrics, for example horizontal force (F_H), and can negatively affect global performance via a lower contribution of F_H from the weak leg.[1,2] Asymmetry is also speculated to potentially increase the risk of injury as the strong leg begins to work at the upper limit of its physical capacity and the weak leg is unable to endure such effort.[3,4] Practically defined, F_H is the forwardly oriented portion of ground reaction force production and is central to sprint acceleration.[5] Moreover, the measurement of F_H forms the basis on which force-velocity profiling can be performed as an assessment tool to determine asymmetry and guide training periodization.[5,6]

In sprinting, targeted rehabilitation programming can affectively decrease F_H asymmetry between legs[7]; therefore, a physiotherapist might focus on improving the strength of the weak leg relative to the strong leg, to decrease asymmetry and potentially reduce injury risk (eg, hamstring tear).[3] Hip extension strength has also been related to sprint acceleration performance via global F_H[8]; therefore, a strength and conditioning practitioner might target the development of this capacity to improve global F_H production.[9] Both examples illustrate the same theoretical undertones of targeted strength training for increased performance, and reinforce the need for physiotherapist and strength and conditioning personnel to collaborate for the physical conditioning of athletes (prevention and performance).

Instrumented nonmotorized treadmill (NMT) ergometry allows for sport-specific collection and analyses of asymmetry in F_H and performance indicators (ie, maximal velocity [v_{max}] and power [P_{max}]) within the same maximal sprint trial.[10] While NMTs are seldom used in the field, the purpose of this research was to demonstrate a proof of concept acknowledging the theoretical link between asymmetry in F_H and global performance in the case of sprinting. To accomplish our purpose, we aimed to (1) profile the sprint performance of a single athlete on a NMT and assess any asymmetry in F_H; (2) prescribe and assess the effects of a targeted strength training program aimed at enhancing F_H in the weak leg (ie, decreasing asymmetry); and (3) determine the influence and practical implications of decreasing F_H asymmetry on global sprint performance.

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Methods

Athlete Description

One male athlete (age, 29 y; height, 188.1 cm; body mass, 100.6 kg) participated in this case study. The athlete's sport background comprised participation in rugby union, sevens, and touch with >4 years of gym-based weight training averaging 3 to 5 sessions per week. At the start of the investigation, the athlete had concluded participation in competitive touch rugby and had no current injuries, was fully informed of all aspects of the research, and provided written informed consent. All procedures were approved by the Auckland University of Technology Ethics Committee (#13/378).

Study Design

This study employed repeated observations on a single athlete. Meaningful inferences were assessed regarding the true value of the effect statistic resulting from a pre-post training intervention. The athlete performed four 6-second maximal sprints on a NMT, at the same day and time, once per week for 12 weeks. Weeks 1 to 6 were used as the pretest (control block), weeks 7 to 9 were not included in the statistical analysis (transition block; determined post hoc via nonuniformity of the data), and weeks 10 to 12 were used as the posttest (intervention block) for comparison.

Data Collection

The athlete examined in this case study was well versed in using NMTs. A complete description of testing terminology, equipment, procedures, and data analysis and reduction can be found elsewhere in detail.[10] Briefly, the athlete performed a standardized dynamic warm-up and then was attached to the NMT via a nonelastic tether to perform a sprint-specific warm-up. The NMT warm-up consisted of running at ~2 $m \cdot s^{-1}$ for ~2 minutes and then using a "block start" while performing 3 submaximal sprints for ~8 seconds at 50%, 70%, and 80% and a single short maximal trial for ~3 seconds. A 3-minute rest followed each sprint.

The maximal sprint testing consisted of an initial "unbraked" sprint (0% of electromagnetic maximum) and 3 subsequent randomized "braked" sprints (33%, 66%, and 99%). Asymmetry in F_H was calculated from the unbraked sprints using a modified (absolute value) symmetry angle equation.[11] Sprint performance was modeled using methods recently presented,[12] where composite force-velocity and power-velocity relationships were calculated (linear and polynomial fitting, respectively) at v_{max} using the 4 braking conditions (0%, 33%, 66%, and 99%). Mechanical profiles were calculated from maximal sprint efforts across the 12 weeks.

Intervention Program

During the control block, the athlete maintained a strict strength training regime with no additional sprint training. Following the control block, a consistent strong and weak leg of the athlete was determined based on the discrete kinetic data observed from each leg during each of the unbraked sprints over the course of the 6 weeks (see control block data; Figure 1). Targeted unilateral hip extension exercises (3 × velocity-based and 3 × strength-based),[7,9,13] were strategically implemented in the weak leg in addition to the current bilateral strength training regime for the ensuing 6 weeks (Table 1). A Certified Strength and Conditioning Specialist® ensured the intervention exercises slowly progressed with a linear decrease in total volume (sets × reps) and a linear increase in intensity (resistance exercise-specific rating of perceived exertion [RPE][14]). The total training volume was maintained across the 12 weeks as to not introduce an additional stimulus effect between the control block and intervention block.

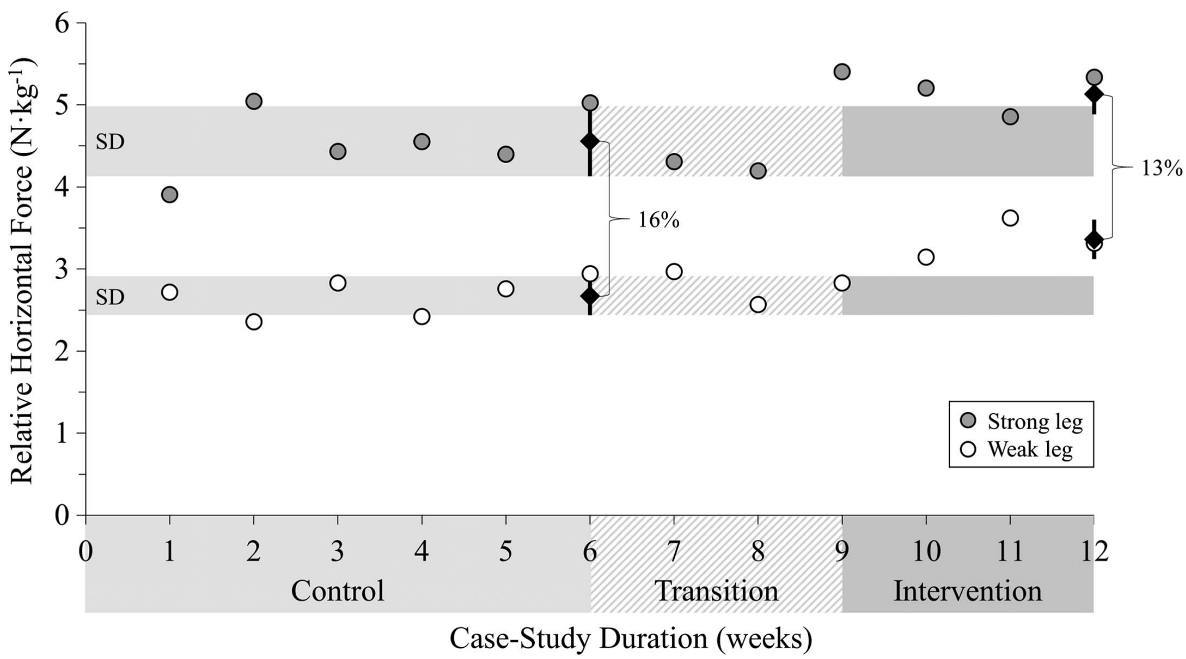

Figure 1 — Relative horizontal force (Newtons per kilogram [$N \cdot kg^{-1}$]) produced during maximal sprinting on the instrumented nonmotorized treadmill for each individual leg across the 12 weeks. Solid gray and white circles represent the strong and weak legs, respectively. Solid black diamonds with vertical bars represent means and SD during the control block (weeks 1–6) and intervention block (weeks 10–12). Percentages are asymmetry scores for the difference between the means of the 2 legs at the end of the control block and intervention block. Shaded areas (solid light gray, dashed medium gray, and solid medium gray) correspond to case study block (control, transition, and intervention).

Table 1 Targeted Hip-Extension Exercises Implemented Into the Strength-Training Regimen for the 6-Week Intervention

		Control	Transition			Intervention		
Day	**Exercise and training emphasis**	**Weeks 1–6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**
Monday	Banded kick-backs[a]	—	3 × 10 RPE 3	3 × 9 RPE 4	3 × 8 RPE 5	2 × 10 RPE 6	2 × 9 RPE 6.5	2 × 8 RPE 7
	Pistol squat[b]	—	2 × 4 BM	2 × 5 BM	2 × 6 BM	3 × 4 BM	3 × 5 BM	3 × 6 BM
	Traditional training "power" emphasis	✓	✓	✓	✓	✓	✓	✓
Wednesday	Sprint test	✓	✓	✓	✓	✓	✓	✓
	SL triple-bound[a]	—	2 × 1 distance	2 × 1 distance	3 × 1 distance	3 × 1 distance	4 × 1 distance	4 × 1 distance
	SL Romanian deadlift[b]	—	4 × 7 RPE 5	4 × 6 RPE 6	4 × 5 RPE 6.5	3 × 6 RPE 7	3 × 5 RPE 7.5	3 × 4 RPE 8
	Traditional training "hypertrophy" emphasis	✓	✓	✓	✓	✓	✓	✓
Friday	Split-squat jump[a]	—	3 × 5 BM	3 × 5 BM	3 × 420 kg	3 × 420 kg	3 × 340 kg	3 × 340 kg
	SL hip thrust[b]	—	3 × 10 RPE 5	3 × 9 RPE 6	3 × 8 RPE 6.5	2 × 10 RPE 7	2 × 9 RPE 7.5	2 × 8 RPE 8
	Traditional training "strength" emphasis	✓	✓	✓	✓	✓	✓	✓

Abbreviations: BM, body mass; kg, kilogram; RPE, resistance exercise-specific rating of perceived exertion; SL, single leg; ✓, task completed.
Note. Values are presented as sets and reps.
[a] Velocity-based exercise. [b] Strength-based exercise.

Statistical Analysis

Means and standard deviations were calculated for F_H (individual leg), v_{max}, and P_{max} during the control block and intervention block to determine whether the intervention elicited a greater effect than the within-athlete error alone. The Pre-post crossover.xls spreadsheet (sportsci.org) was used to derive magnitude-based inferences for the pretest to posttest effects. Threshold values of <0.2, 0.2, 0.6, 1.2, and 2.0 (representing trivial, small, moderate, large, and very large differences, respectively) were used to assess the magnitude of the standardized effect. Uncertainty in the estimates were expressed at 90% confidence limits and as a probability that the true value of the effect was substantially positive or negative.[15]

Results

While mean changes in F_H in the strong leg were unclear, mean changes in the weak leg presented clear and very large (2.7 to 3.4 $N \cdot kg^{-1}$; ES = 2.2; +26%) improvements between the control block and intervention block, producing a moderate decrease in F_H asymmetry (16 to 13%; ES = −0.65; −19%) (Figure 1). The athlete also experienced moderate and very large improvements in v_{max} (5.86 to 6.01 $m \cdot s^{-1}$; ES = 0.67; +2%) and P_{max} (18 to 21 $W \cdot kg^{-1}$; ES = 3.2; +15%) between the control block and intervention block, respectively (Figure 2).

Discussion

Individual F_H contribution from each leg and global performance during sprinting showed encouraging and beneficial alterations. These changes are likely resultant of the targeted hip extension exercises increasing F_H in the weak leg, subsequently reducing asymmetry; thus the global elevation of F_H is likely the cause of the observed increases in mechanical sprint measures. Importantly, this case study was the first of knowledge to show that a training regime, predominantly targeting hip extensor strength capacities, reduced F_H asymmetry. This finding is of note, given the prevalence of posterior chain injuries during sprinting bouts and the contribution of this mechanism to sprint performance.

These results illustrate that increasing F_H production ability of the weak leg also improved the athlete's global and mechanical sprinting outputs (ie, positive shift in force and velocity capacities, and associated increase in P_{max}; Figure 2). An interpretation of this finding may be that the athlete could have decreased his risk of injury while improving his basic acute performance. Considering an athlete's global ability to sprint is reliant on the sum of its parts, a weak leg may limit the system's ability to sprint faster. Additionally, it could be speculated that both legs and adjacent structures (pelvis, spine) may experience unnecessary or even hazardous stress due to exceeding physical capacities or imbalance-related compensations. The data presented in this case study favors the notion that greater hip extension strength is linked to performance[8] during sprinting. However, more information is required to support the proposed[4] link between lower hip extension strength and increased hamstring injuries in sprinting.

As this single athlete may have simply been a "responder" to our intervention stimulus, a full-scale controlled investigation should be implemented. Increasing athletic performance is the primary goal in all sports, so too should be reducing injury risk via decreasing asymmetry. If this concept holds true, perhaps the fundamental methods of strength training prescription will be altered for the better; and thus our athletes could experience less injuries, with either no change to or positive effects on performance.

Practical Applications

Targeted training of a weak leg can increase F_H and decrease asymmetry. Increasing the strength of a weak leg also increases: (1) 2-legged force application (capability to produce high level of

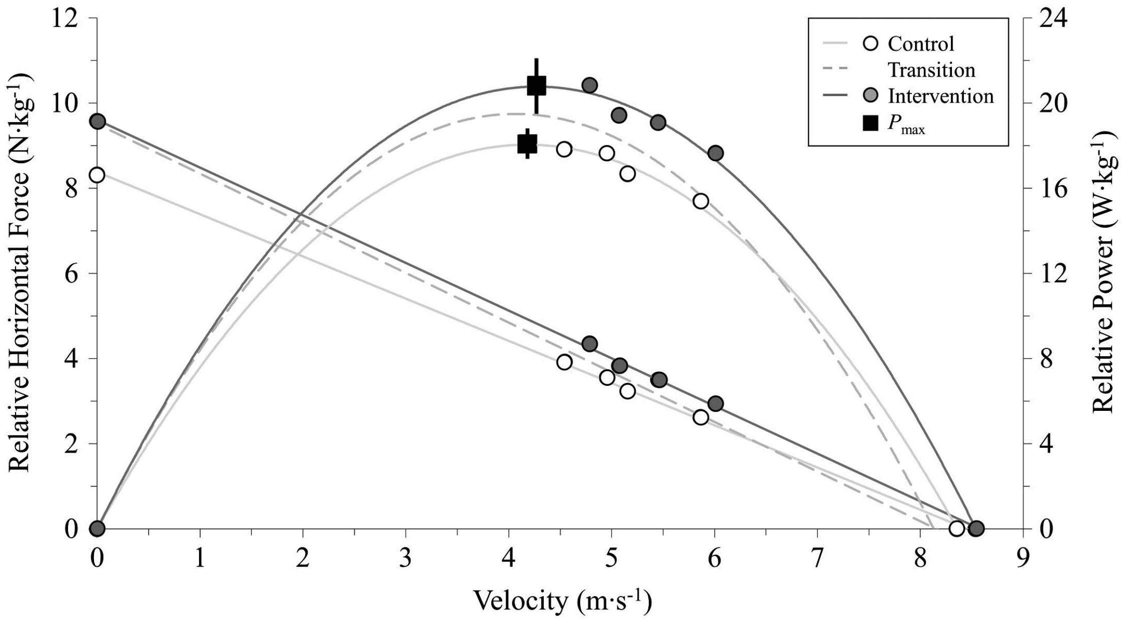

Figure 2 — Force-velocity-power sprint profiling on the instrumented nonmotorized treadmill with 4 loads (0 [unbraked], 33, 66, and 99%). Solid white circles and solid light gray lines represent control block (weeks 1–6), dashed medium gray lines represent transition block (weeks 7–9), and solid gray circles and solid medium gray lines represent intervention block (weeks 10–12). Solid black diamonds with vertical bars represent mean maximal power (P_{max}) and SD. All linear force-velocity and polynomial power-velocity fits showed $R^2 > .999$.

F_H at slow velocities); and (2) global sprint velocity (capability to produce high level of F_H at high velocities).

References

1. Mendiguchia J, Edouard P, Samozino P, et al. Field monitoring of sprinting power-force-velocity profile before, during and after hamstring injury: two case reports. *J Sports Sci*. 2016;34:535–541. PubMed doi:10.1080/02640414.2015.1122207
2. Exell T, Irwin G, Gittoes M, Kerwin D. Strength and performance asymmetry during maximal velocity sprint running. *Scand J Med Sci Sports*. 2017;27(11):1273–1282. PubMed doi:10.1111/sms.12759
3. Ammann R, Taube W, Wyss T. Gait asymmetry during 400 to 1000 m high-intensity track running in relation to injury history. *Int J Sports Physiol Perform*. 2017;12(suppl2):S2157–S2160. PubMed doi:10.1123/ijspp.2016-0379
4. Sugiura Y, Saito T, Sakuraba K, Sakuma K, Suzuki E. Strength deficits identified with concentric action of the hip extensors and eccentric action of the hamstrings predispose to hamstring injury in elite sprinters. *J Orthop Sports Phys Ther*. 2008;38:457–464. PubMed doi:10.2519/jospt.2008.2575
5. Cross MR, Brughelli M, Samozino P, Morin J-B. Methods of power-force-velocity profiling during sprint running: a narrative review. *Sports Med*. 2017;47(7):1255–1269. PubMed doi:10.1007/s40279-016-0653-3
6. Morin J-B, Samozino P. Interpreting power-force-velocity profiles for individualized and specific training. *Int J Sports Physiol Perform*. 2016;11:267–272. PubMed doi:10.1123/ijspp.2015-0638
7. Brughelli M, Nosaka K, Cronin J. Application of eccentric exercise on an Australian rules football player with recurrent hamstring injuries. *Phys Ther Sport*. 2009;10:75–80. PubMed doi:10.1016/j.ptsp.2008.12.001
8. Morin J-B, Gimenez P, Edouard P, et al. Sprint acceleration mechanics: the major role of hamstrings in horizontal force production. *Front Physiol*. 2015;6:1–14. PubMed doi:10.3389/fphys.2015.00404
9. Contreras B, Vigotsky AD, Schoenfeld BJ, et al. Effects of a six-week hip thrust versus front squat resistance training program on performance in adolescent males: a randomized-controlled trial. *J Strength Cond Res*. 2017;31(4):999–1008. PubMed doi:10.1519/JSC.0000000000001510
10. Brown SR, Brughelli M, Cross MR. Profiling sprint mechanics by leg preference and position in rugby union athletes. *Int J Sports Med*. 2016;37:890–897. PubMed doi:10.1055/s-0042-109067
11. Zifchock RA, Davis I, Higginson J, Royer T. The symmetry angle: a novel, robust method of quantifying asymmetry. *Gait Posture*. 2008;27:622–627. PubMed doi:10.1016/j.gaitpost.2007.08.006
12. Cross MR, Brughelli M, Samozino P, Brown SR, Morin J-B. Optimal loading for maximizing power during sled-resisted sprinting. *Int J Sports Physiol Perform*. 2017;12(8):1069–1077. doi:10.1123/ijspp.2016-0362
13. Mendiguchia J, Martínez-Ruiz E, Morin J-B, et al. Effects of hamstring-emphasized neuromuscular training on strength and sprinting mechanics in football players. *Scand J Med Sci Sports*. 2015;25:e621–e629. PubMed doi:10.1111/sms.12388
14. Zourdos MC, Klemp A, Dolan C, et al. Novel resistance training–specific rating of perceived exertion scale measuring repetitions in reserve. *J Strength Cond Res*. 2016;30:267–275. PubMed doi:10.1519/JSC.0000000000001049
15. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41:3–13. PubMed doi:10.1249/MSS.0b013e31818cb278