Fontys University of Applied Sciences

Physiotherapy

The Effect of Kinematic Chain Manipulative Therapy on the Frontal Plane Knee Movement in Cycling

Kitty Schiphorst Preuper

Mentor: Steven Onkelinx

Client: B-Fysic Sportmáx

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Voorwoord

Met veel plezier heb ik afgelopen periode gewerkt aan mijn scriptie 'The effect of kinematic chain manipulative therapy on the frontal plane knee movement in cycling'. Het onderzoek is geschreven in de periode van februari tot en met juni 2016 in kader van mijn afstuderen als fysiotherapeut aan de Fontys Paramedische Hogeschool Eindhoven. Het onderzoek is uitgevoerd in opdracht van B-Fysic en in samenwerking met Maxima Medisch Centrum Sportmáx.

In samenwerking met mijn stagebegeleider Bart van den Beek ben ik tot de onderzoeksvraag van mijn scriptie gekomen. Het onderzoek was uitdagend omdat er samenwerking van verschillende disciplines bij vereist was en er nog weinig onderzoek is gedaan naar dit onderwerp. Dankzij de flexibele houding en expertise van bewegingswetenschapper Joep van Kesteren en orthopedisch manueel therapeut Bart van den Beek verliep alles echter volgens plan.

Bij deze wil ik hen dan ook graag bedanken voor de fijne samenwerking en begeleiding tijdens het traject. Daarnaast wil ik graag mijn Fontys begeleider Steven Onkelinx en alle vrijwilligers die mee hebben gewerkt aan dit onderzoek hartelijk bedanken.

In het speciaal nog een dankwoord aan Hugo van Nuland, bewegingswetenschapper en fysiotherapeut bij B-fysic. Hij heeft mij geweldig geholpen met het wetenschappelijke deel van mijn scriptie en stond meerdere keren paraat om mijn documenten kritisch en op schrijffouten te beoordelen. Dankzij zijn goede hulp kon ik telkens vooruit en ben ik tot dit eindresultaat gekomen.

Ik wens u veel leesplezier toe.

Kitty Schiphorst Preuper

Eindhoven, mei 2016

The Effect of Kinematic Chain Manipulative Therapy on the Frontal Plane Knee Movement in Cycling

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Abstract

Purpose: The aim of this study was to evaluate the effect of kinematic chain manipulative therapy on the frontal plane knee movement in cycling. **Methods:** in this study 13 amateur cyclists aged between 25 and 65 years old participated and underwent kinematic chain manipulative therapy executed by a professional orthopaedic manual therapist. Before and after the intervention the frontal plane knee movement was measured in a cycling trail using a 3D motion analyse system. **Results:** Eight out of thirteen subjects (62%) showed a decreased- and three subjects showed an increased frontal plane knee movement. The mean difference before and after manipulative therapy was a decrease of 2 mm ± 2,6 (mean ± SD). A t-test revealed a statistically significant difference between the frontal plane movement before- and after kinematic chain manipulative therapy (P=0,041). **Conclusion:** The study shows a decreased trend in frontal plane knee movement in cyclists but further research with a bigger research group will be needed before drawing any firm conclusions.

Because of the good quality of cycling paths and great performance of Dutch professional cyclists, the population of active cyclists in 2014 in the Netherlands has been increased to 815.000 (1). Cycling may be a low-impact sport but it is also very repetitive: a cyclist may average up to 5000 pedal revolutions per hour (2,3). Therefore, the smallest change whether anatomic or equipment related can lead to dysfunction, decreased performance, pain and chronic or overuse injuries (2,3).

The knee is, with 50%, the most common site of overuse in cyclists (4,5). Knee pain is frequently caused by patellofemoral pain syndrome (PFPS) or “cyclist’s knee” and iliotibial band (ITB) friction syndrome (2,6–9). Most of the time an overuse knee injury find its origin in a change of intrinsic or extrinsic factors like incorrect bike fit, increase in training distance or intensity, pushing big gears or training in hills or windy conditions (3,5). The repetitive flexion and extension of the knee during cycling and the force generated by the quadriceps muscle contraction is translated to the patellofemoral joint which results in injury of the patella or the iliotibial band (3,6).

Because of the normal valgus angulation of the distal femoral condyles relative to the femoral shaft, the knee does not move straight up and down in the frontal plane but moves in a clockwise circular motion. When pushing down on the pedal the knee extends and adducts and when the pedal returns to the top the knee flexes and abducts (2,10) as shown in Figure 1.

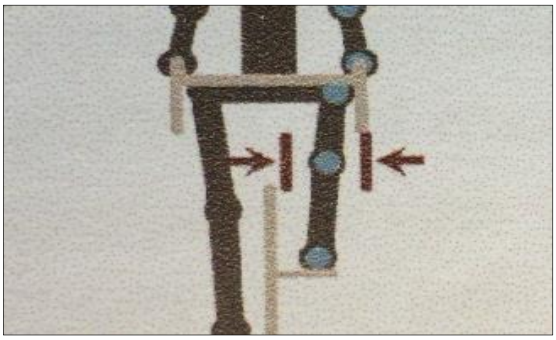

Figure 1 *Frontal plane knee movement*

The frontal plane knee angles in healthy cyclists range from 2 to 4 degrees of abduction to 1 to 6 degrees of adduction (10,11). This mediolateral frontal plane knee movement during the downward pedal stroke in cycling seems to play an important role in the development of overuse injuries like PFP and ITB syndrome (3,11–15).

Cyclists with knee injuries show an abnormal frontal plane knee movement pattern during the down stroke (10). This abnormal pattern generates too much pressure on the patellofemoral joint or creates an impingement angle at the bottom of the down stroke which can cause pain. Research has shown that after a ‘normalization’ of the frontal plane knee movement by using a special pedal for the foot whereby the cyclists show a linear path when viewed in the frontal plane, the symptoms of cyclist with knee pain decreased (1). An important and effective way to reduce the frontal plane knee movement and the strain on the lateral side of the knee through varus load, is proper adjustment of the saddle height, cleat position, the type of cleat and shoe in combination with stabilisation training of the hip muscles (2,6,8,12,14–16).

The inversion- and eversion angles of the subtalar joint of the foot has influence on the frontal plane knee movement and has even been suggested as a cause of PFPS (17,18). On average a 10-degree everted position of the foot significantly decreases the mediolateral frontal plane knee movement (19). This suggests that joints of the lower extremities have an effect on the frontal plane knee movement and the limitation in range of motion would negatively influence this. Brantingham et al found fair evidence for manipulative therapy of the full kinematic chain including subtalar-, ankle-, knee-, hip-, lumbar- and thoracic joints for PFPS (20). In addition, lumbopelvic manipulation can cause a short time positive effect on the activation and strength of the quadriceps muscle and decrease knee pain in subjects with PFPS (21–23) and it is already performed after cycling crashes (5). However, no research has been done about the effect of kinematic chain manipulations on the frontal plane knee movement.

Kinematic chain manipulation could reduce knee injuries that are common in cycling (20–23) but the influence of kinematic chain manipulations on the frontal plane knee movement, which causes a lot of knee overuse injuries in cycling is unknown. Therefore, the purpose of this experimental prospective study will be to evaluate the effect of kinematic chain manipulative therapy on the frontal plane knee movement in cycling.

Methods

Experimental Approach to the Problem. The purpose of this experimental prospective pilot study will be to evaluate the effect of kinematic chain manipulative therapy on the frontal plane knee movement in cycling.

Subjects. Before participating in this study all voluntary subjects were informed about the procedure, completed a written informed consent form (Appendix I) and a brief questionnaire about their body composition, training and injury status (Appendix II). A total of 13 subjects (12 male and 1 female) aged between 25 and 65 participated on this study. The subjects were all cyclists participating in a dynamic bike fitting analysis at Maxima Medisch Centrum Sportmáx in Eindhoven the Netherlands.

A previous physical examination ensured that all subjects were in good health and no contra-indications for manipulative therapy were present.

Procedures. Subjects report to the laboratory with their own bike. The bicycle seat, handlebar and cleats are adjusted to match each cyclists personal preferred geometry by an experienced movement scientist. The cyclists wear their own clothing and shoes. The subjects were asked to cycle at a comfortable work rate while the frontal plane knee movement was measured. The mean frontal plane knee movement is noted in millimetres.

The frontal plane knee movement of the right knee is evaluated by the dynamic three dimensional (3D) motion analyse system Bioracer Motion. It uses 6 cameras, 8 wireless body markers attached as shown in Figure 2 and records in 120 frames per second to make a very accurate analysis of the cyclists movements.

***Figure 2** Body markers during measurements*

The trail is followed by a physical examination of the body including the subtalar-, ankle-, knee-, hip-, lumbopelvic- and thoracic joint (2) executed by an experienced orthopaedic manual therapist. If any movement deficits where found, the treating practitioner would adjust this using manipulative therapy. The manipulative procedures are only executed when indication of a dysfunctional movement was found in the physical examination.

The following joints are examined and treated with an end range high- or low- velocity (traction) thrust manipulation as shown in Figure 3:

1. Subtalar joint
2. Ankle joint
3. Knee
4. Hip
5. Lumbopelvic spine
6. Thoracic spine

Figure 4a: *Manipulation of the subtalar joint*

Figure 3b: *Endorotation manipulation of the knee*

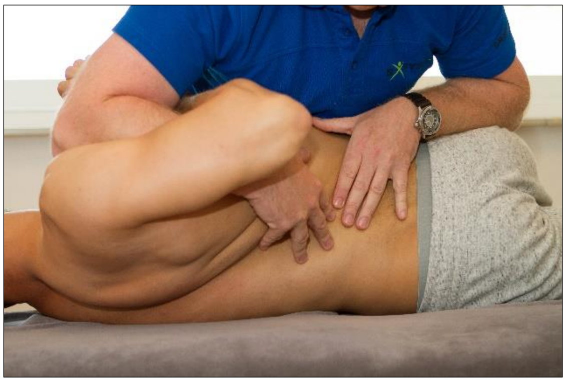

Figure 3c: *Manipulation of the lumbopelvic spine*

Figure 3d: *Manipulation of the thoracic spine*

After the kinematic chain manipulative therapy intervention, subjects return to the laboratory and repeat the dynamic cycling trail. Subjects are instructed to cycle at the same work rate and cadence as before. The frontal plane knee movement is noted and compared to the frontal plane knee movement before the intervention of kinematic chain manipulative therapy.

Table 1 Baseline characteristics

	Mean	SD
Age in years	44	12
Height in cm	181	7
Weight in kg	80	9
Experience in years	8	9
Training hours p/w	6	2

Statistical Analysis. Because of the small population of subjects, descriptive statistics like the mean and standard deviation are used to evaluate this experimental prospective pilot study. The gender, body compositions, training intensity and injury status is noted for each subject. Each restricted- and adjusted joint is noted after the physical examination of the body and the intervention of manipulative therapy.

The mean frontal plane knee movement before the intervention of kinematic chain manipulative therapy is noted in millimetres and compared using a paired T-test to the frontal knee movement before and after the intervention of kinematic chain manipulative therapy.

Results

Thirteen subjects (12 male and 1 female) enrolled in the study. Their age, height, weight, experience and training hours per week are shown in Table 1.

One subject did not meet the inclusion criteria of keeping the same cadence and therefore is not included in the results (Appendix IV). All subjects where cyclists on an amateur level, one subject participated on a mountain bike and one on a tracking bike. Two subjects did not have cycling as their first sport. Three of the subjects experienced traumatic injuries like bruised or broken bones and one suffered from neck pain. Two cyclists had overuse knee injuries in the past and six of the subjects (50%) never experienced an injury.

All patients underwent the physical examination by an orthopaedic manual therapist including the subtalar-, ankle-, knee-, hip-, lumbopelvic- and thoracic joint. All patients showed a movement restriction in the thoracic spine, eleven in the lumbopelvic spine and the knee.

Only one subject showed a restriction in the ankle. Adjustments were made to restricted joints as shown in Appendix III.

Twelve subjects showed a change in the frontal plane knee movement immediately following the kinematic chain manipulative therapy. Eight out of thirteen subjects (62%) showed a decreased- and three subjects showed an increased frontal plane knee movement. The marker path of the right knee before and after the intervention in Figure 3 shows an example of an decreased frontal plane knee movement. The mean difference before and after manipulative therapy was a decrease of 2 mm ± 2,6 (mean ± SD). A t-test revealed a statistically significant difference between the frontal plane movement before- and after kinematic chain manipulative therapy (P=0,041). The frontal plane knee movement in millimetres-, the mean and standard deviation before and after the kinematic chain manipulative therapy and the relative change for each subject are shown in Table 2.

Discussion

The aim of this study was to evaluate the effect of kinematic chain manipulative therapy on the frontal plane knee movement in cycling. This study shows an average decrease of the frontal plane knee movement of 7%. This finding strengthens the argument that kinematic chain manipulative therapy could have a positive effect on the frontal plane knee movement in cycling and in that way reduce injury risk.

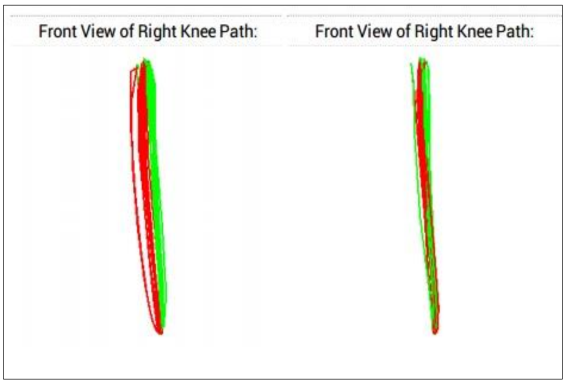

Figure 4a *Marker path of the right knee before intervention*
Figure 4b *Marker path of the right knee after intervention*

As mentioned in the introduction researches found significant greater abduction moment in the frontal plane in cyclists with a history of an overuse knee injury, indicating that a more medial knee position relative to the ankle has a potential to disturb the knee joint pattern and increases the risk of overuse knee injuries (10,11,14, 24).

As the recent study only shows frontal plane knee movement in millimetres which is the average of each stroke's difference between the maximum and minimum lateral position of the knee, and not the abduction and adduction spreading it is hard to link this to previous studies. Other studies indicate that less movement in the frontal plane are related to a lower knee injury risk. The observed trend for a decreased frontal plane knee movement after kinematic chain manipulative therapy in this study suggest a more optimal knee joint pattern and in that way could reduce overuse knee injury risk.

Table 2. Frontal plane knee movement in mm, the mean and standard deviation before and after kinematic chain manipulative therapy and the relative change

Subject	Before in mm	After in mm	Relative change
1	25	19	24%
2	38	35	7,9%
3	21	20	4,7%
4	12	12	0%
6	22	20	9,1%
7	14	12	14,3%
8	38	37	2,6%
9	19	15	21%
10	20	21	-5%
11	32	33	-3,1%
12	22	24	-9,1%
13	42	36	14%
Mean	25	24	7%
Standard deviation	9,8	9,2	0,1

Eight subjects in this study showed a decreased frontal plane knee movement which could suggest a better cycling position and less injury risk. The decrease in frontal plane knee movement followed by the kinematic chain manipulative therapy could be a result of an increased range of motion (6), improved proprioception and -joint stability (7). Recent studies have shown that spinal manipulation can improve the transversus abdominis and lumbar multifidus activation (8,9). Improving activity of these muscles could lead to an improved spinal stiffness and result in a better frontal plane knee movement (10).

Three subjects showed an increased frontal plane knee movement after the kinematic chain manipulative therapy. A possible explanation for the increased frontal plane knee movement is the subjects athletic ability, overall fitness or a poor core stability.

Muscles that maintain a strong and stable pelvis play an important role in the lower limb movements and protect the knee joint from excessive frontal plane knee movements (10). The subjects fitness could affect the ability of muscle stabilisation followed by the created mobility in the frontal plane knee movement.

Recent studies showed an abnormal frontal plane knee movement pattern in cyclists with overuse knee injury history (3) as found in subject 5 and 11. Another explanation could be a coordination deficit and reduced motor unit synchronization in relation to the previous overuse knee injury in these subjects which makes them unable to generate an active control of the joint mobility (11).

Because of the small population an outlier has an enormous influence on the results. Subject's 5 mean cadence before the intervention was so different from the mean cadence after that the subject is excluded from the research as the results are not valid to compare (Appendix IV).

Limitations and recommendations

There are a number of limitations in this study. The major limitation is the small popularity (N=13) with one outlier which has influence on the outcome measures. We cannot relate any cause and effect relationship between kinematic chain manipulative therapy and the changes in frontal plane knee movement because there was no control group included in this study.

The study only investigated the immediate effects of kinematic chain manipulative therapy on the frontal plane knee movement but there was no long term follow up so no conclusions can be drawn about this effects over time.

A statistically significant difference (P=0,041) was found in the frontal plane knee movement before- and after kinematic chain manipulative therapy but no hard conclusions can be drawn out of this because of the small popularity. To truly evaluate the effect of kinematic chain manipulative therapy on the frontal plane knee movement in cycling a randomized clinical trial with a larger population is necessary.

Another limitation is the individual preference and experience of the manual therapist which makes it hard to iterate similar studies in the future. Unless this study shows a clear method, the personal preference and technique of each therapist will be different.

Because of practical reasons there was no possibility to equalize the cadence and work rate for each subject and only one side of the body was tested. To improve this in the future, the dynamic cycling trail could be recorded under controlled power and cadence conditions (12,13) and both sides are suggested to be tested.

Subjects did not know the research was focussing on the knee movement but expectations of the patient and placebo effect cannot be ignored as a potential source of the subjects response (14).

Conclusion

The change in frontal plane knee movement between before- and after kinematic chain manipulative therapy is statistically significant and show a decreased trend. This could result in a less excessive knee pattern during cycling and in that way reduce overuse injury risk. Further research with a bigger research group and a randomized clinical trial with a placebo or control group approach will be needed before drawing any firm conclusions.

References

1. NTFU, Benelux BM, GfK. Onderzoek naar omvang & profiel van de Nederlandse wielersport. Ned wielersportmonitor 2014. 014;33(2):81–7.
2. Asplund C, St Pierre P. Knee pain and bicycling: fitting concepts for clinicians. *Phys Sportsmed.* 2004;32(4):23–30.

3. Holmes JC, Pruitt AL, Whalen NJ. Iliotibial band syndrome in cyclists. *Am J Sports Med*. 1993;21(3):419–24.
4. Bini R, Hume PA, Croft JL. Effects of Bicycle saddle height on knee injury risk and cycling performance. *Sports Med.* 2011. p. 463–76.
5. Silberman MR. Bicycling injuries. *Curr Sports Med Rep*. 2013;12(5):337–45.
6. Schwellnus MP, Derman E. Common injuries in cycling: prevention, diagnosis and management. *South African Fam Pract.* 2006;47(7):14–9.
7. De Bernardo N, Barrios C, Vera P, Laíz C, Hadala M. Incidence and risk for traumatic and overuse injuries in top-level road cyclists. *J Sports Sci.* 2012;30(10):1047–53.
8. Perrin AE. Cycling-Related Injury. *Connecticut Medicine.* 2010;76(8):461–7.
9. Dettori NJ, Norvell DC. Non-Traumatic Bicycle Injuries A Review of the Literature. *Sports Med.* 2006;36(1):7–18.
10. Bailey MP, Maillardet FJ, Messenger N. Kinematics of cycling in relation to anterior knee pain and patellar tendinitis. *J Sports Sci*. 2003;21(8):649–57.
11. Umberger BR, Martin PE. Testing the Planar Assumption During Ergometer Cycling. *Hum Kinet Publ.* 2001;17:55–62.
12. Gregersen CS, Hull ML. Non-driving intersegmental knee moments in cycling computed using a model that includes three-dimensional kinematics of the shank / foot and the effect of simplifying assumptions. *J Biomech.* 2003;36:803–13.
13. Boyd TF, Neptune RR, Hull ML. Pedal and knee loads using a multi-degree-of-freedom pedal platform in cycling. *J Biomech.* 1997;30(5):505–11.
14. Wolchok JC, Hull ML, Howell SM. The effect of intersegmental knee moments on patellofemoral contact mechanics in cycling. *J Biomech*. 1998;31:677–83.
15. Hawkins D, Hull ML, Ruby P. Three-dimensional knee joint loading seated cycling. *J Biomech.* 1992;25(1):41–53.
16. Zyl E Van. A Review of the Etiology, Biomechanics, Diagnosis, and Management of Patellofemoral Pain in Cyclists. *Int Sport J.* 2001;2(1):1–34.
17. Dewhurst P. Conservative management of patellofemoral pain syndrome: What is the best approach? *Clin Chiropr.* 2009;12(2):79–82.
18. Tiberio D. The effect of excessive subtalar joint pronation on patellofemoral mechanics: a theoretical model. *J Orthop Sports Phys Ther.* 1987;9(4):160–5.
19. Gregersen CS, Hakansson NA. How Changing the Inversion / Eversion Foot Angle Affects the Nondriving Intersegmental Knee Moments and the Relative Activation of the Vastii Muscles in. *J Biomech Engeneering.* 2006;128(6):391–8.
20. Brantingham JW, Globe G, Pollard H, Hicks M, Korporaal C, Hoskins W. Manipulative Therapy for Lower Extremity Conditions: Expansion of Literature Review. *J Manipulative Physiol Ther.* 2009;32(1):53–71.
21. Grindstaff TL, Hertel J, Beazell JR, Magrum EM, Ingersoll CD. Effects of lumbopelvic joint manipulation on quadriceps activation and strength in healthy individuals. *Man Ther.* 2009 Aug [cited 2016 Feb 19];14(4):415–20.
22. Jayaseelan DJ, Courtney CA, Kecman M. Lumbar manipulation and exercise in the management of anterior knee pain and diminished quadriceps activation following ACL reconstruction: a case report. *Int J Sports Phys Ther.* 2014;9(7):991–1003.
23. Crowell MS, Wofford NH. Lumbopelvic manipulation in patients with patellofemoral pain syndrome. *J Man Manip Ther.* 2012;20(3):113–20.
24. Hannaford DR, Moran GT, Hlavac HF. Video analysis and treatment of overuse knee injury in cycling: a limited clinical study. *Clin Podiatr Med Surg.* 1986;3:671–8.
25. Banesto D. Preferred pedalling cadence in professional cycling. *Med Sci Sport Exerc.* 2000;1361–6.
26. Fang Y. Effects of Cycling Workload and Cadence on Frontal Plane Knee Load. *Masters Theses.* 2014;
27. Cross KM, Kuenze C, Grindstaff T, Hertel J. Thoracic Spine Thrust Manipulation Improves Pain, Range of Motion, and Self-Reported Function in Patients With Mechanical Neck Pain: A Systematic Review. *J Orthop Sport Phys Ther*. 2011;41(9):633–42.
28. Learman KE, Myers JB, Lephart SM, Sell TC, Kerns GJ, Cook CE. Effects of Spinal Manipulation on Trunk Proprioception in Subjects With Chronic Low Back Pain During Symptom Remission. *J Manipulative Physiol Ther.* National University of Health

Sciences; 2009;32(2):118–26.
29. Koppenhaver SL, Fritz JM, Hebert JJ, Kawchuk GN, Childs JD, Parent EC, et al. Association between changes in abdominal and lumbar multifidus muscle thickness and clinical improvement after spinal manipulation. *J Orthop Sports Phys Ther.* 2011;41(6):389–99.
30. Fritz JM, Koppenhaver SL, Kawchuk GN, Teyhen DS, Hebert JJ, Childs JD. Preliminary investigation of the mechanisms underlying the effects of manipulation: exploration of a multivariate model including spinal stiffness, multifidus recruitment, and clinical findings. *Spine*. 2011;36(21):1772–81.
31. Powers CM. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther.* 2010;40(2):42–51.
32. Mellor R, Hodges PW. Motor unit syncronization is reduced in anterior knee pain. *J Pain.* 2005;6(8):550–8.
33. Iverson CA, Sutlive TG, Crowell MS, Morrell RL, Perkins MW, Garber MB, et al. Lumbopelvic Manipulation for the Treatment of Patients With Patellofemoral Pain Syndrome: Development of a Clinical Prediction Rule. *Journal of Orthopaedic and Sport Physical Therapy*. 2008;297–312.

Appendix I Informed consent

Ik verklaar hierbij dat ik op duidelijke wijze ben ingelicht over de aard en methode van het onderzoek door middel van mondelinge uitleg en het informatieblad. Mijn vragen zijn naar tevredenheid beantwoord.

Ik stem geheel vrijwillig in met deelname aan dit onderzoek. Ik behoud daarbij het recht deze instemming weer in te trekken zonder dat ik daarvoor een reden hoef op te geven. Ik besef dat ik op elk moment mag stoppen met het experiment. Als mijn onderzoeksresultaten gebruikt worden in wetenschappelijke publicaties, of op een andere manier openbaar worden gemaakt, dan zal dit volledig geanonimiseerd gebeuren. Mijn persoonsgegevens worden niet door derden ingezien zonder mijn uitdrukkelijke toestemming.

Voor meer informatie over dit onderzoek kunt u te allen tijde contact opnemen met de projectleider Kitty Schiphorst Preuper (k.schiphorstpreuper@student.fontys.nl).

Email adres als u geïnteresseerd bent in de resultaten van het onderzoek:

Handtekening voor toestemming deelname: Datum:

Ik heb toelichting verstrekt op het onderzoek. Ik verklaar mij bereid nog opkomende vragen over het onderzoek naar vermogen te beantwoorden. Als er tijdens het onderzoek informatie bekend wordt die de toestemming van de proefpersoon zou kunnen beïnvloeden, dan breng ik hem/haar daarvan tijdig op de hoogte.

Naam onderzoeker: Handtekening:

Kitty Schiphorst Preuper

Appendix II Questionnaire

Hartelijk dank voor uw deelname aan het onderzoek!

Graag wil ik u verzoeken om de onderstaande vragen in te vullen. U mag doorstrepen wat niet van toepassing is.

Geslacht	man / vrouw
Leeftijd	
Lengte	
Gewicht	
Hoofdsport	wielrennen / mountainbiken / triatlon anders namelijk:
Jaren fietservaring:	
Niveau	amateur / regionaal / nationaal / internationaal
Fietsuren per week:	
Bent u in uw fiets carrière geblesseerd geweest?	ja / nee
Zo ja, wat voor blessure?	
Bent u bekend met de volgende klachten? - Aandoeningen van het bot - Neurologische aandoening van het ruggenmerg - Vasculaire aandoeningen	 ja / nee ja / nee ja / nee

Voor meer informatie over dit onderzoek kunt u te allen tijde contact opnemen met de projectleider Kitty Schiphorst Preuper (k.schiphorstpreuper@student.fontys.nl).

Met vriendelijke groet,

Kitty Schiphorst Preuper
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Appendix III Manipulative therapy per subject

Subjects		1	2	3	4	5	6	7	8	9	10	11	12	13
Subtalar		-	-	-	-	-	-	-	-	-	-	-	-	-
Ankle		-	R	-	-	-	-	-	-	-	-	-	-	-
Knee	**Flexion**	-	-	-	-	-	R	R	-	-	-	-	R	-
	Endorotation	R	R	R	R	R	x	R	L	-	L	R		L
Hip	**Flexion**	-	-	-	-	-	-	-	-	-	-	-	-	-
Lumbar spine	**Lateroflexion**	R	R	R	L	x	R	L	L	-	L	R	R	L
Thoracic spine	**Rotation**	x	x	x	x	x	x	x	x	x	x	x	x	x

Appendix IV Frontal plane knee movement and cadence

	FPKM before	FPKM after	Cadence mean before	Cadence mean after
1	25	19	86	85
2	38	35	102	101
3	21	20	90	82
4	12	12	80	82
5	37	48	79	66
6	22	20	101	99
7	14	12	105	102
8	38	37	91	93
9	19	15	76	69
10	20	21	82	79
11	32	33	93	94
12	22	24	109	111
13	42	36	72	77