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The effect of hamstring /quadriceps muscle strength ratio on plantar pressure distribution - A pilot study

Esedullah Akaras[1], Nevin Aysel Güzel[2], Gamze Çobanoğlu[3], Zeynep Berfu Ecemiş[2], Batuhan Ünal Şimşek[4]

[1] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Erzurum Technical University, Erzurum, Türkiye. [2] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Gazi University, Ankara, Türkiye. [3] Güneysu Vocational School of Physical Therapy and Rehabilitation, Recep Tayyip Erdoğan University, Rize, Türkiye [4] Sipay Bodrum FK, Muğla, Türkiye.

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Abstract

The interaction between agonist and antagonist muscles, particularly the quadriceps and hamstrings, is critical in knee joint biomechanics, impacting its stability and functionality during movement. This study investigates the relationship between the hamstring/quadriceps (H/Q) muscle strength ratio and plantar pressure distribution in the foot during walking. Utilizing dynamic pedobarography and isokinetic dynamometry, we assessed 19 male participants (Age: 25.22±3.33 years; BMI: 22.64 ± 2.39 kg/m^2) to measure plantar pressure and muscle strength ratios. Our findings indicate significant correlations between muscle strength imbalances and variations in plantar pressure, suggesting that both the H/Q ratio and individual muscle strengths are influential in foot biomechanics. Specifically, increased hamstring strength relative to the quadriceps was associated with higher plantar pressure on the heel, while a lower H/Q ratio correlated with increased pressure on the forefoot and toes. These insights may underscore the importance of balanced muscle function for maintaining proper gait mechanics and preventing lower extremity injuries. The study highlights the necessity of integrating muscle strength assessments in clinical evaluations to enhance musculoskeletal health and functional mobility.

Introduction

The complex interaction between agonist and antagonist muscles is of great importance in the knee joint biomechanics, managing its functionality and stability during various movements. Specifically, the quadriceps and hamstring muscles, located in the anterior and posterior thigh regions, respectively, emerge as significant players in this musculoskeletal symphony. Recent research highlights the critical role of the quadriceps and hamstring muscles in maintaining optimal knee joint function (Coombs & Garbutt, 2002). Weakness, shortening, or injury-induced imbalances in these muscle groups can disrupt the harmonious balance of the biomechanical system of the knee and impair its functionality (Palmieri-Smith et al., 2009). These imbalances go beyond merely localized effects, affecting the kinetic chains responsible for maintaining postural integrity and facilitating precise movement patterns (Bennell et al., 1998).

A standard measure to assess the balance between knee flexors and extensors is the hamstring/quadriceps ratio (H/Q), usually assessed via isokinetic dynamometry. This method provides valuable information regarding peak torque, a parameter that is indicative of the maximum torque produced during movement at certain speeds, indicating whether muscle imbalance is present. Understanding these ratios is particularly important in light of their relationship to mitigating anterior shear forces during knee extension, a phenomenon observed in activities that require rapid and robust knee movements. Furthermore, the effects of muscle imbalances extend beyond the knee joint, penetrating the complex kinetic chain network and potentially affecting gait biomechanics (Dugan & Bhat, 2005). Establishing and maintaining a balanced and functional relationship between muscle chains and agonist and antagonist muscles emerges as the cornerstone in preventing overuse injuries and preserving the delicate balance of the knee joint (Vincent et al., 2022). Suppose the hamstring muscle is

✉ E. Akaras, e-mail: esedullah.akaras@erzurum.edu.tr
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stronger than the quadriceps. In that case, this pushes the pelvis backward, and the pressure on the heels increases, leading to problems such as tendonitis in the Achilles muscle (Park & Chou, 2006).

Dynamic pedobarographies measure plantar pressure during the gait cycle. Previous studies have reported successful applications of pedobarography in evaluating plantar pressure changes in lower extremity pathologies and in the functional evaluation of lower extremity surgeries (Cetin et al., 2017; Rongies et al., 2009). Proper alignment and weight distribution are crucial for reducing pressure on the feet and preventing foot pain or injuries (Ledoux & Hillstrom, 2002). We hypothesize that when the quadriceps and hamstrings are equally strong, they can work together to distribute weight and support the body evenly. This can help reduce plantar pressure and prevent overuse injuries. In addition, just as changes in the foot can affect the upper extremity, changes in the upper extremity also affect the lower extremity (Braz & Carvalho, 2010). Since we do not know of any study that affects the plantar pressure distribution of the hamstring quadriceps muscle ratios, we decided to investigate their relationship. Specifically, we will explicitly highlight how the relationship between muscle strength ratios (H/Q) and plantar pressure distribution during walking has been underexplored and why it is crucial to study this interaction for enhancing foot biomechanics and preventing lower extremity injuries. This article aims to investigate the relationship between the quadriceps and hamstring muscle strength ratios and the plantar pressure distributions during walking.

Methods

Participants

The study was conducted in the Sports Health unit of the Physiotherapy and Rehabilitation Department of Gazi University. The necessary ethics committee approval (04.05.2021-08-561) was obtained from the relevant university. All participants signed the voluntary participation form, and the study was conducted in accordance with the Helsinki Declaration. Within the scope of the study, sociodemographic information of 19 male individuals (Age: 25.22±3.33 years; BMI: 22.64±2.39 kg/m^2) was recorded before. Before the gait analysis, the participants' body compositions were measured with the Tanita BC 480 device.

Inclusion criteria

Young male adults aged 18-30 years who declared that they volunteered to participate in the study and signed the written consent form.

Exclusion criteria

1) Subjects with a history of injury, surgery or chronic pain in the lower extremities within the last 6 months. 2) Individuals with deformity, inequality or neuromuscular disease of the lower extremities. 3) Individuals with systemic diseases that may affect the results of the study, such as diabetes, cardiovascular disease or obesity. 4) Individuals who will not be able to fully fulfill working procedures.

Procedure

The pedobarographic assessment was performed with the Rs Scan-FootScan® V9 (Olen, Belgium, 2096 mm × 472 mm × 18 mm, with a 256 × 64 matrix at a resolution of 2 sensors/cm2, frequency; 125 Hz, pressure range; 0–200 N/cm2) device. Static measurements were performed with the individual standing on the pressure sensor platform, with both bare feet, in a relaxed stance position, looking at a fixed point in front. They were asked to wear as light clothing as possible. Dynamic measurements were performed after the individuals performed three trial walks on the platform (Wang et al., 2022). Individuals were asked to walk as fast and as fast as possible in their daily walking pace and pattern, always looking straight ahead. The average values of 3 dynamic measurements for each foot were obtained and the results were recorded. At the end of the dynamic assessments, the maximum pressure values (N/cm²) and contact times under the first toe, 2nd, 3rd, 4th, and fifth toes, 1st, 2nd, 3rd, 4th, and fifth metatarsals, midfoot, heel medial and heel lateral were measured and recorded (Monteiro et al., 2010). Figure 1 illustrates the plantar pressure system that divides the foot into ten zones.

As illustrated in Figure 1, the foot scan plate system partitioned the foot into the following ten anatomical regions: (I) to 1 (T1), (II) toes 2 to 5 (T2-5), (III) metatarsal 1 (M1), (IV) metatarsal 2 (M2), (V) metatarsal 3 (M3), (VI) metatarsal 4 (M4), (VII) metatarsal 5 (M5), (VIII) midfoot (MF), (IX) heel medial (HM), and (X) heel lateral (HL).

Then, the participant warmed up on a bicycle ergometer for 5 minutes. Then, the hamstring and quadriceps muscle strengths were measured with the Cybex Humac Norm 360 device, with the dominant foot of the individual first, by performing five repetitions at a speed of 60°/sec, concentrically and eccentrically. Three repetitions were performed to learn the movement before the measurement. Then, the individuals' hamstring/quadriceps muscle strength ratio was recorded. During the test, verbal instructions were given in equal tones to get the best performance from all participants and to motivate them (Akaras et al., 2023).

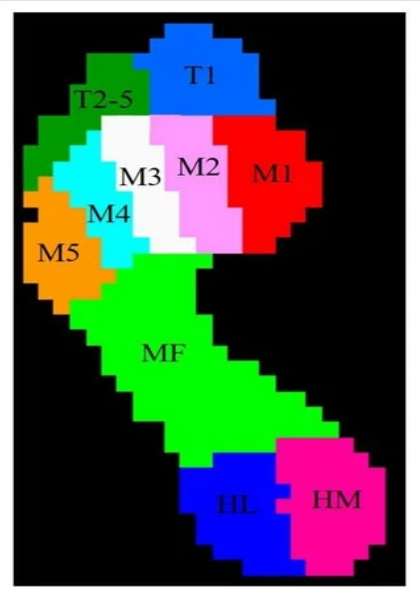

Figure 1. The Plantar pressure system that divides the foot into ten zones: (Ⅰ) toe 1 (T1), (Ⅱ) toes 2 to 5 (T2-5), (Ⅲ) metatarsal 1 (M1), (Ⅳ) metatarsal 2 (M2), (Ⅴ) metatarsal 3 (M3), (Ⅵ) metatarsal 4 (M4), (Ⅶ) metatarsal 5 (M5), (Ⅷ) midfoot (MF), (Ⅸ) heel medial (HM), and (Ⅹ) heel lateral (HL).

The sample size was found to be α = 0.05; β = 0.80, 16 participants, when Dowling's (Dowling et al., 2004) study was taken as a reference. Individuals with knee and ankle pain, disability, injury, chronic disease that may affect the lower extremity in the last six months, lower extremity inequality and foot deformity were not included in the study.

Data Analyses

All relevant analyses were performed in SPSS version 20 (SPSS Inc., Chicago, IL, USA). Whether the parameters were normally distributed or not was examined with Kolmogorov-Smirnov and Shapiro-Wilk tests. Spearman method was selected due to the non-parametric nature of our data, as the variables did not meet the assumptions required for parametric tests. Spearman correlation is appropriate for examining the monotonic relationship between variables, which aligns with the nature of the data and research objectives. The relationship between the values was examined using Spearman correlation analysis. A significant *p* value was taken as <0.05.

Results

Demographic information of all participants was recorded (Table 1).

Table 1
Subjects' demographic information (n=19).

Variables	Mean ± SD
Age (years)	25.22 ± 3.33
Height (cm)	172.83 ± 9.76
Weight (kg)	67.93 ± 11.24
BMI (kg/m^2)	22.64 ± 2.39

Dominant foot toe1 contact time was significantly associated with 60°/sec eccentric non-dominant quadriceps femoris muscle strength (p<0.05). Dominant foot toe1 contact time was significantly associated with 60°/sec eccentric strength of non-dominant hamstring muscle (p<0.05). Dominant foot toe 2-5 contact time was significantly associated with 60°/sec eccentric strength of dominant quadriceps femoris muscle (p<0.05). Dominant foot toe 2-5 contact time was significantly associated with 60°/sec eccentric non-dominant quadriceps femoris muscle strength (p<0.05; Table 2).

Dominant foot meta2 maxP was significantly associated with 60°/sec concentric strength of dominant hamstring muscle (p<0.05; Table 3).

Non-dominant toe1_touch was found to be significantly associated with 60°/sec concentric strength of the non-dominant hamstring muscle (p<0.05). Non-dominant midfoot was found to be significantly associated with 60°/sec eccentric strength of the dominant hamstring muscle (p<0.05). A significant association was found between non-dominant midfoot and dominant side eccentric H/Q ratio (p<0.05; Table 4).

Non-dominant Meta1maxP contact time was found to be significantly associated with 60°/sec eccentric strength of the dominant hamstring muscle (p<0.05). Non-dominant Meta1maxP contact time was found to be significantly associated with the 60°/sec eccentric strength of the non-dominant hamstring muscle (p<0.05). A significant relationship was found between non-dominant Meta5maxP contact time and dominant side eccentric H/Q ratio (p<0.05). A significant relationship was found between non-dominant midfootmaxP contact time and 60°/sec concentric strength of non-dominant hamstring muscle (p<0.05). A significant relationship was found between the non-dominant midfootmaxP contact time and the non-dominant concentric H/Q ratio (p<0.05; Table 5).

Table 2
Relationship between dominant plantar foot contact time and muscle strength.

Variables		dqf 60con	ndqf 60con	dh 60con	ndh 60con	Dqf 60ecc	ndqf 60ecc	dh 60ecc	ndh 60ecc	dcon HQratio	nd conHQratio	decc HQratio	ndecc HQratio
dtoe1t	r	0.241	0.187	0.065	-0.099	0.401	.615*	0.506	.678*	-0.082	0.015	0.044	-0.364
	p	0.368	0.522	0.812	0.737	0.174	**0.033**	0.078	**0.015**	0.771	0.958	0.887	0.245
dtoe2-5	r	0.358	0.299	0.329	-0.121	.644*	.655*	0.164	0.294	-0.132	-0.348	-0.360	-0.550
	p	0.174	0.299	0.213	0.680	**0.018**	**0.021**	0.593	0.353	0.638	0.223	0.226	0.064
dmeta1	r	0.200	-0.272	0.296	-0.296	0.094	0.286	0.044	0.102	0.220	-0.237	-0.100	-0.318
	p	0.459	0.348	0.265	0.303	0.760	0.367	0.886	0.751	0.430	0.415	0.746	0.314
dmeta2	r	0.132	0.044	0.170	0.020	-0.094	0.021	0.048	-0.056	-0.025	-0.090	-0.030	-0.021
	p	0.626	0.881	0.528	0.946	0.761	0.948	0.875	0.862	0.929	0.759	0.922	0.948
dmeta3	r	0.339	0.254	0.253	0.097	0.019	0.109	0.054	-0.056	-0.215	-0.163	-0.240	-0.126
	p	0.199	0.382	0.344	0.742	0.950	0.737	0.861	0.863	0.441	0.578	0.430	0.696
dmeta4	r	0.377	0.260	0.255	0.029	0.066	0.200	0.106	-0.007	-0.202	-0.244	-0.250	-0.200
	p	0.150	0.368	0.341	0.923	0.830	0.534	0.730	0.983	0.470	0.400	0.409	0.534
dmeta5	r	0.374	0.128	0.287	-0.068	0.099	0.266	0.063	0.077	-0.202	-0.138	-0.242	-0.252
	p	0.153	0.663	0.281	0.817	0.748	0.404	0.837	0.812	0.470	0.637	0.426	0.430
dmidfoot	r	-0.070	-0.201	-0.004	-0.048	-0.295	-0.137	-0.353	-0.316	-0.225	0.150	-0.248	0.133
	p	0.797	0.491	0.987	0.869	0.328	0.672	0.237	0.317	0.419	0.609	0.414	0.680
dheelmedial	r	0.192	-0.004	0.087	0.004	-0.182	0.074	-0.139	-0.021	-0.359	0.026	-0.146	0.067
	p	0.475	0.988	0.749	0.988	0.552	0.820	0.650	0.948	0.188	0.929	0.634	0.837
dheellat	r	0.139	-0.020	0.024	-0.035	-0.242	-0.039	-0.208	-0.186	-0.412	-0.018	-0.215	0.102
	p	0.607	0.946	0.929	0.905	0.426	0.905	0.495	0.564	0.127	0.952	0.481	0.753

Table 3
Relationship between dominant foot maximum plantar pressure values and muscle strength.

Variables		Dh 60con	Ndh 60con	Dqf 60ecc	Ndqf 60ecc	Dh 60ecc	Ndh 60ecc	Dcon HQratio	Ndcon HQratio	Decc HQratio	Ndecc HQratio
dtoe1maxP	r	-0.163	-0.156	0.335	0.175	0.151	0.392	-0.271	0.297	-0.104	-0.105
	p	0.546	0.594	0.263	0.587	0.622	0.208	0.328	0.303	0.734	0.746
dtoe2-5maxP	r	-0.170	-0.328	-0.118	-0.182	-0.114	0.053	-0.229	-0.097	-0.105	0.301
	p	0.529	0.252	0.700	0.571	0.710	0.871	0.413	0.742	0.734	0.341
dmeta1 maxP	r	0.010	-0.477	0.407	0.350	0.014	0.168	-0.079	-0.147	-0.132	-0.329
	p	0.970	0.085	0.168	0.265	0.964	0.602	0.781	0.615	0.668	0.297
dmeta2 maxP	r	.517*	0.334	0.413	0.476	0.496	0.557	0.444	-0.057	0.391	-0.249
	p	**0.040**	0.243	0.161	0.117	0.085	0.060	0.098	0.846	0.187	0.436
dmeta3 maxP	r	0.330	0.130	0.236	0.182	0.135	0.070	0.354	-0.292	0.071	-0.056
	p	0.212	0.659	0.437	0.572	0.661	0.829	0.196	0.311	0.817	0.863
dmeta4 maxP	r	0.141	0.160	0.022	-0.098	-0.399	-0.483	0.114	-0.143	-.582*	-0.056
	p	0.602	0.584	0.943	0.762	0.177	0.112	0.685	0.626	**0.037**	0.863
dmeta5 maxP	r	-0.045	-0.154	-0.107	-0.277	-0.405	-0.515	0.107	-0.046	-0.487	0.067
	p	0.869	0.599	0.727	0.384	0.170	0.087	0.703	0.875	0.091	0.837
dmidfoot maxP	r	-0.038	-0.031	-0.118	-0.302	-0.457	-.582*	0.120	-0.048	-0.446	0.091
	p	0.890	0.917	0.700	0.340	0.117	**0.047**	0.670	0.869	0.126	0.778
dheelmedial maxP	r	0.305	0.119	0.091	0.455	.596*	.634*	0.141	-0.279	.669*	-0.067
	p	0.251	0.686	0.768	0.137	**0.031**	**0.027**	0.616	0.333	**0.012**	0.837
dheellat maxP	r	0.359	0.251	0.171	0.158	0.394	0.102	0.095	-0.365	0.437	-0.035
	p	0.172	0.387	0.577	0.625	0.183	0.753	0.737	0.199	0.135	0.914

Table 4
Relationship between non-dominant plantar foot contact time and muscle strength.

Variables		Dqf60con	Ndqf60con	Dhamst60con	Ndhams60con	Dqf60ecc	Ndqf60ecc	Dhamstr60ecc	Ndhamst60ecc	dconHQ ratio	ndconHQratio	DeccHQratio	ndeccHQratio
ndToe1_touch	r	0.056	0.236	0.278	.626*	0.066	0.067	0.232	0.161	0.230	0.313	0.408	0.049
	p	0.836	0.416	0.297	**0.017**	0.830	0.837	0.446	0.617	0.410	0.276	0.167	0.880
ndtoe2ve5	r	0.112	0.307	0.207	0.082	0.249	0.240	-0.022	0.145	0.115	-0.075	-0.102	0.056
	p	0.681	0.286	0.442	0.781	0.412	0.453	0.943	0.654	0.684	0.798	0.739	0.862
ndmeta1	r	-0.047	-0.190	-0.019	-0.312	0.453	0.120	0.230	0.099	0.154	-0.213	-0.050	-0.373
	p	0.862	0.516	0.944	0.277	0.120	0.711	0.450	0.760	0.583	0.464	0.872	0.232
ndmeta2	r	0.072	-0.023	0.084	-0.289	0.425	0.158	0.134	0.095	0.181	-0.278	-0.262	-0.400
	p	0.790	0.937	0.756	0.317	0.148	0.624	0.663	0.770	0.517	0.336	0.387	0.198
ndmeta3	r	-0.038	0.048	-0.030	0.057	0.273	-0.007	0.033	0.053	0.090	0.104	-0.193	-0.257
	p	0.890	0.872	0.913	0.845	0.366	0.983	0.914	0.870	0.750	0.724	0.527	0.420
ndmeta4	r	0.009	0.153	0.062	0.201	0.180	-0.053	-0.078	-0.028	0.127	0.115	-0.166	-0.138
	p	0.974	0.602	0.820	0.490	0.556	0.870	0.801	0.931	0.652	0.695	0.587	0.670
ndmeta5	r	-0.031	0.041	-0.101	0.192	0.050	-0.134	-0.154	-0.184	-0.201	0.009	-0.187	-0.152
	p	0.909	0.889	0.709	0.510	0.870	0.677	0.616	0.568	0.473	0.976	0.540	0.637
ndmidfoot	r	-0.327	-0.205	-0.276	-0.265	-0.086	-0.295	-.630*	-0.418	-0.156	0.077	-.618*	0.056
	p	0.216	0.483	0.300	0.360	0.781	0.351	**0.021**	0.176	0.579	0.793	**0.024**	0.862
ndheelmedial	r	0.112	-0.101	0.062	0.327	-0.516	-0.464	-0.294	-0.290	-0.417	0.288	0.086	0.407
	p	0.678	0.731	0.819	0.253	0.071	0.129	0.329	0.360	0.122	0.319	0.780	0.189
ndheellateral	r	0.048	-0.071	0.042	0.355	-0.532	-0.488	-0.366	-0.421	-0.404	0.278	0.044	0.445
	p	0.860	0.810	0.877	0.212	0.061	0.108	0.219	0.173	0.135	0.336	0.886	0.147

Discussion

This study examined the relationship between the strength of the quadriceps and hamstring muscles and the hamstring/quadriceps (H/Q) ratio with plantar pressure distribution in the foot. The findings revealed significant correlations between muscle strength and plantar pressure in various regions of the foot, highlighting the intricate interplay between lower limb muscle function and foot biomechanics. Our study observed that when the hamstring and quadriceps eccentric muscle strength on the non-dominant side increased, the contact time at the dominant side toe tip increased. When the H/Q ratio increased on the dominant side, the contact time at the contralateral foot midfoot region increased. The pressure on the big toe increased as the dominant and non-dominant hamstring eccentric muscle strength increased. When the non-dominant side hamstring muscle strength increased, the pressure increased in the midfoot region of the same foot.

The human foot plays a significant role in the biomechanical function of the lower extremities, which includes providing balance and supporting the body when walking. The morphological and physiological characteristics of the foot can alter not just with age-related skeletal growth but also with lower limb motor control, gait development, and how pressure is distributed throughout the foot when walking (Phethean & Nester, 2012). Researchers and clinicians frequently employ plantar pressure analysis to identify foot illnesses, which gauges the distribution of foot pressure. A greater understanding of various lower limb musculoskeletal problems may also be gained in light of the altered foot plantar pressure distribution (Monteiro et al., 2010). Our findings highlight the importance of muscle balance for maintaining proper foot biomechanics. Clinicians may consider incorporating isokinetic strength testing and plantar pressure analysis into routine evaluations to identify potential risk factors for musculoskeletal disorders and tailor interventions accordingly. Such an approach could be particularly beneficial for populations at higher risk of lower extremity injuries, such as athletes or individuals recovering from orthopedic surgeries.

Table 5
Relationship between non-dominant foot maximum plantar pressure values and muscle strength.

Variables		dqf 60con	ndqf60con	dh60con	ndh60con	dqf60ecc	ndqf60ecc	dh60ecc	ndh60ecc	dconHQratio	ndconHQratio	deccHQratio	ndeccHQratio
ndToe1maxP	r	0.104	0.110	0.150	0.068	0.113	0.266	0.320	0.322	0.150	0.029	0.259	-0.098
	p	0.702	0.708	0.578	0.817	0.714	0.404	0.287	0.308	0.593	0.923	0.394	0.762
nd_Toe2-maxP	r	0.144	-0.064	0.315	0.126	-0.111	-0.127	0.053	0.138	0.396	0.267	0.163	0.085
	p	0.594	0.828	0.235	0.668	0.719	0.694	0.864	0.670	0.144	0.356	0.594	0.794
ndMeta1maxP	r	0.337	0.086	0.369	0.037	0.429	0.462	.765**	.636*	0.246	-0.002	0.467	-0.294
	p	0.202	0.770	0.159	0.899	0.144	0.131	**0.002**	**0.026**	0.376	0.994	0.108	0.354
ndMeta2maxP	r	0.193	-0.026	0.315	-0.218	0.335	0.308	0.206	-0.056	0.354	-0.130	-0.011	-0.462
	p	0.474	0.929	0.235	0.455	0.263	0.331	0.499	0.863	0.196	0.659	0.972	0.131
ndMeta3maxP	r	-0.273	-0.211	-0.200	-0.471	-0.129	-0.060	-0.463	-0.228	0.267	-0.321	-0.174	0.193
	p	0.307	0.470	0.458	0.089	0.673	0.854	0.111	0.477	0.337	0.263	0.571	0.549
ndMeta4maxP	r	0.190	0.077	0.121	-0.200	0.044	0.217	-0.088	-0.049	0.225	-0.473	-0.033	-0.021
	p	0.481	0.793	0.656	0.493	0.887	0.499	0.775	0.880	0.420	0.088	0.915	0.948
ndMeta5maxP	r	0.094	0.076	0.041	-0.273	0.338	0.242	-0.215	-0.259	-0.055	-0.378	-.792**	-0.522
	p	0.728	0.796	0.882	0.345	0.258	0.449	0.481	0.416	0.845	0.182	**0.001**	0.082
ndmidfootmaxP	r	0.097	-0.236	0.074	-.598*	0.118	0.067	-0.220	-0.459	-0.113	-.532*	-0.528	-0.406
	p	0.722	0.417	0.784	**0.024**	0.700	0.837	0.469	0.134	0.689	**0.050**	0.064	0.190
ndheelmedialmaxP	r	0.423	0.330	0.482	0.398	-0.055	0.189	0.248	0.343	0.474	0.037	0.462	0.182
	p	0.102	0.249	0.059	0.159	0.859	0.557	0.415	0.276	0.075	0.899	0.112	0.572
ndheellateralmaxP	r	0.130	0.281	0.217	0.354	-0.050	0.165	0.175	0.473	.518*	0.383	0.382	0.175
	p	0.632	0.330	0.419	0.214	0.872	0.609	0.568	0.121	0.048	0.177	0.197	0.586

Pedobarography is one of the most widely used methods to evaluate the interaction of the foot and the contacting support surface during standing or walking in a bipedal position. Plantar pressure, which is the pressure exerted by the foot on the ground during activities such as walking, is crucial for understanding gait and posture. Abnormal plantar pressure distributions can indicate lower extremity issues and help diagnose various foot conditions. Proper plantar pressure distribution is essential for balance and body support during walking. The characteristics of the foot, including morphological and physiological aspects, can influence plantar pressure and change with factors such as skeletal growth, motor control development, and gait patterns. Plantar pressure distribution measurements could serve as a valuable tool in clinical settings for monitoring biomechanical changes during rehabilitation. Regular assessments may provide insights into the effectiveness of therapeutic interventions and help clinicians adjust treatment plans to improve functional outcomes and prevent injury recurrence.

Foot plantar pressure occurs between the foot and the support surface and is essential in daily locomotor activities. The plantar pressure measurement information obtained here is vital in diagnosing walking and posture and determining lower extremity problems. However, the relationship between eccentric hamstring strength and plantar pressure distribution is less commonly explored directly. But eccentric hamstring exercises are known to improve overall muscle control and stability, which are crucial for efficient movement and load distribution during activities like running and jumping (Jakobsen et al., 2012). Improved hamstring strength could potentially lead to better plantar pressure distribution by enhancing lower limb stability and function.

Quadriceps dysfunction can result in abnormal gait patterns characterized by smaller knee flexion angles, reduced sagittal knee moments, and increased ground reaction forces. Additionally, increased knee varus angles and abnormal frontal knee moments have been implicated in the mechanical pathogenesis of knee problems. The quadriceps muscle plays a vital role in mitigating loading during the early stance phase of gait. Dysfunction in the quadriceps can lead to impulsive loading, which in turn may contribute to knee problems. The relationship between hamstring and quadriceps strength and plantar pressure distribution is crucial in understanding overall lower limb biomechanics. Balanced muscle strength is essential for proper gait mechanics, which in turn influences plantar pressure distribution. As seen in individuals, quadriceps dysfunction can lead to altered gait patterns and uneven plantar pressure distribution, further exacerbating the risk of musculoskeletal disorders.

Our study found that when the H/Q ratio increased on the dominant side, the contact time in the contralateral midfoot region increased. We also found that the pressure on the big toe increased as the dominant and non-dominant hamstring eccentric muscle strength increased. The following conclusions are possible in light of these results. When the quadriceps are significantly stronger than the hamstrings (low H/Q ratio), the pelvis tilts forward, facilitating a general recurvature of the knee and increasing loading on the forefoot (Yazdani et al., 2016). This imbalance may lead to higher pressure on the forefoot and toes. Conversely, if the hamstrings are more robust relative to the quadriceps (high H/Q ratio), there can be a posterior tilt of the pelvis and increased load on the heel. This imbalance might result in higher pressure on the heel and midfoot. The observed relationship between H/Q ratios and plantar pressure distribution suggests that assessing and addressing muscle strength imbalances could play a crucial role in designing personalized rehabilitation protocols. For instance, targeted strengthening exercises to improve H/Q balance may help optimize gait mechanics and reduce the risk of overuse injuries in athletes and physically active individuals.

The limitations of our study are that we could not reach more subjects and we could not measure the strength of the tibial and core region muscles. Further research with larger sample sizes and diverse populations is needed to validate these findings and explore the underlying mechanisms driving the observed relationships. Longitudinal studies also help determine the long-term effects of muscle strength training on plantar pressure and lower extremity biomechanics. Understanding these connections will enhance our ability to develop effective prevention and treatment strategies for musculoskeletal disorders and improve overall mobility and quality of life for individuals at risk of lower extremity injuries.

Conclusion

This study highlights the significant associations between quadriceps and hamstring muscle strength, the H/Q ratio, and plantar pressure distribution. Our findings suggest that balanced muscle function might play a role in maintaining proper foot biomechanics; however, these results are limited to the specific population studied and should not be generalized to the broader population without further research. These insights can inform clinical practices and guide future research efforts aimed at enhancing musculoskeletal health and functional mobility. Also, monitoring plantar pressure distribution can provide valuable insights into the effectiveness of rehabilitation interventions and help guide adjustments to optimize outcomes.

Authors' Contribution

Study Design: EA, NAG; Data Collection: GÇ, ZBE, BÜŞ; Statistical Analysis: EA, GÇ, BÜŞ; Manuscript Preparation: EA, NAG; Funds Collection: NAG.

Ethical Approval

The study was approved by the Gazi University Ethical Committee (04.05.2021/08-561) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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