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RESEARCHING OF THE JOINT ANGLES ON THE LEGS, DURING THE SUPPORT PERIOD OF THE MOVE STEP IN CLASSIC MOUNTAIN RUNNING

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ABSTRACT

The purpose of the study is to clarify the kinematic picture of motor activity when overcoming slopes of different steepness in classic mountain running.

Methods: Using a GPS device, the Map Source computer program, and additional mathematical calculations, we explored various mountain running courses to determine their gradient range. We then used the protractor to find terrain with slopes ranging from 0 to 16 degrees in 2-degrees increments for the subjects to run on. By video processing the video files with the computer software Kinovea, we determined the values of the angles of the ankle joint, knee joint and hip joint.

Conclusions: As the inclines of running uphill increase, the angles in all three joints of the lower limbs decrease. In general, there are no large changes in the joint angles of moment of touching the support and the moment of maximum flexing, while at the moment of separation from the support, the joint angles decrease significantly with the increase of the downward slope. At all three moments of the support period (moment of touching the support; maximum flexing; separation from the support) at the different running slopes, the least change of angles was observed in the ankle joint.

Key words*:* Mountain running, Trail running, Off-road running, Kinematic picture of motor activity

INTRODUCTION

Mountain running is an endurance sport practiced in rugged, off-road terrain away from urban environments and stadiums (1, 2). Practicing mountain running in natural conditions with the influence of natural factors – fresh air, sun and diverse ecosystems helps to strengthen health and harmonious human development (3). As a social phenomenon, mountain running is a popular mass sport for health, but it is also an elite and professional sport that requires a very high level of specific training of the competitors (4, 5). This creates the need to search for new approaches through which to realize an advantage in the highly competitive environment of high performance sport (6). Our research is in this direction - to clarify the kinematic structure of mountain running, thus contributing to a more complete understanding of the specifics that are presented to the practitioners of classical mountain running. In our previous research, we found that running inclines ranged from 0 to 16 degrees and examined the kinematic parameters: running speed; stride length; step frequency, support and flight period, deviation of the trunk from the vertical and support angle (4). The current study focused on the support period of the running stride because this is where running speed is built up and lost (7). There are three main moments in the support period: moment of touching the support; moment of maximum flexing; moment of separation from the support (8, 9). We have established average values of the

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leg joint angles at these three moments of the support period of running at the different inclines in classical mountain running.

METHODS

Topography. Using a GPS device, the MapSource computer program, and additional mathematical calculations, various mountain running courses are explored to determine the range of slopes within them.

Goniometry. We used the protractor to find terrain with slopes from 0 to 16 degrees in 2 degree increments. Thus, in the study we included a nine-level system of terrains with different slopes.

Videometry. By video recording and processing the video files with the computer program Kinovea, we determined the values of the joint angles of the lower limbs.

Mathematical and statistical data processing. A variational data processing method was used in the study. The average values of the obtained results were calculated.

RESULTS

The results of the study of the angles of the ankle joint, knee joint and hip joint at the moment of touching the support are presented in **Table 1**.

Table 1. *Average values of the angles in the joints of the lower limbs at the moment of touching the support.*

Moment of touching the support			
Degrees / Percentages of inclination	Ankle joint	Knee joint	Hip joint
16° / 28,6%	90°	110°	115°
14° / 24,9%	92°	118°	117°
12° / 21,2%	93°	125°	120°
10° / 17,6%	94°	128°	124°
8° / 14,0%	94°	132°	129°
6° / 10.5%	95°	139°	132°
4° / 6,9 %	97°	145°	136°
2° / 3,4%	98°	148°	140°
0° / 0%	102°	153°	141°
-2° / -3,4%	104°	163°	140°
-4° / -6,9 %	108°	163°	142°
-6°/ -10.5%	112°	162°	145°
-8° / -14,0%	115°	160°	148°
-10° / -17,6%	115°	160°	151°
-12° / -21,2%	113°	160°	153°
-14°/ -24,9%	110°	164°	154°
-16°/ -28,6%	106°	159°	155°

In running at different slopes, the angles in the joints when meeting the support change significantly. **Figure 1** shows that in all three joints, the angles are the smallest when running uphill against a 16-degree incline, and the trend is for the joint angles to increase when the uphill inclines decrease. The same trend continues when the run is downhill – as the downhill slope increases, the angles become larger. An exception to this are the results showing that when running downhill from -10 to -16 degrees, the angle in the ankle joint begins to decrease. Another interesting exception is that in downhill runs from -2 to -16 degrees, the angle at the knee joint when meeting the support hardly changes. Also, in running up a 2 degrees incline, flat and down to -4 degrees the hip angle is almost the same. The beginning of the stance period (the moment of contact) in a 16-degree ascent starts at 90 degrees at the ankle joint, 110 degrees at the knee joint, and 115 degrees at the hip joint. When running flat, the angles are respectively 102; 153; 141 degrees, and when running down a slope of -16 degrees it is 106; 159; 155 degrees. With the different inclinations, the greatest change is found at the knee joint - 54 degrees, at the hip joint it is 40 degrees, and at the ankle joint it is only 25 degrees.

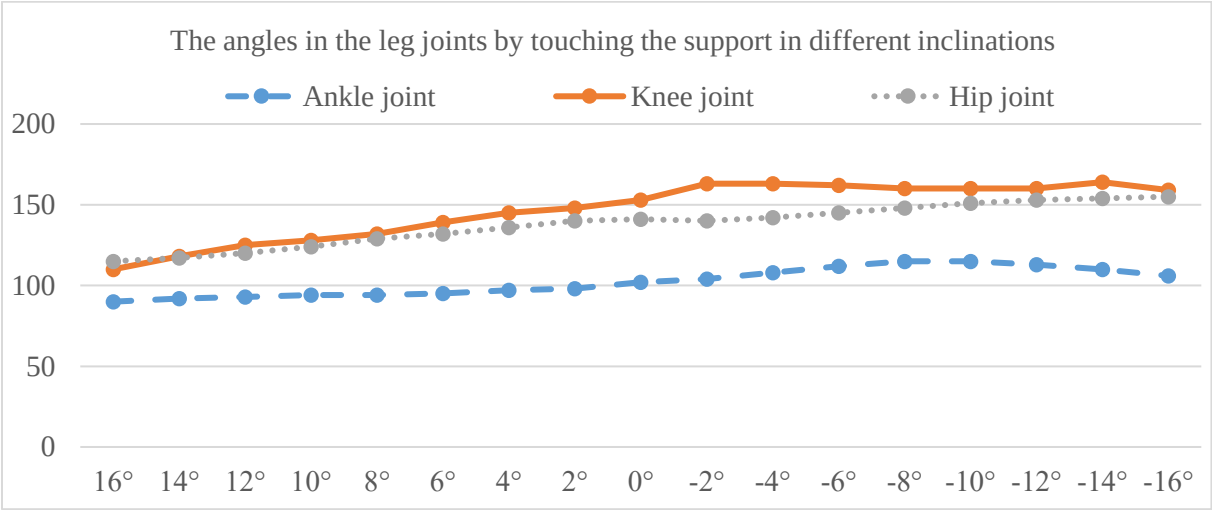

Figure 1. The abscissa shows the values of the angles in the ankle joint, knee joint and hip joint at the moment of touching the support at the different slopes of the route.

The results of the study of the angles of the ankle joint, knee joint and hip joint at the moment of maximum flexing are presented in **Table 2**.

Table 2. *Average values of the angles in the leg joints at the moment of maximum flexing.*

Moment of maximum flexing			
Degrees / Percentages of Inclination	Ankle joint	Knee joint	Hip joint
16° / 28,6%	69°	125°	136°
14° / 24,9%	72°	128°	135°
12° / 21,2%	74°	130°	135°
10° / 17,6%	74°	133°	138°
8° / 14,0%	74°	135°	142°
6° / 10.5%	75°	135°	145°
4° / 6,9 %	75°	134°	148°
2° / 3,4%	75°	134°	154°
0° / 0%	74°	136°	160°
-2° / -3,4%	71°	140°	157°
-4° / -6,9 %	74°	137°	160°
-6°/ -10.5%	75°	135°	161°
-8° / -14,0%	78°	132°	162°
-10° / -17,6%	76°	130°	161°
-12° / -21,2%	75°	131°	160°
-14°/ -24,9%	83°	130°	162°
-16°/ -28,6%	75°	120°	158°

It can be seen in **Figure 2** that there is no large variation in the ankle joint angles at the moment of maximum flexing at the different running slopes. An anomaly was found at the -14 degrees downslope, where the angle was 8 degrees greater than those at -12 and -16 degrees. Excluding this result, the greatest difference in ankle joint angles was 9 degrees—between an upward tilt of 16 degrees and a downward tilt of 8 degrees **(Table 2).** There is greater variation in knee joint angles, where the angle is smallest at the greatest upward tilt (16 degrees) and the greatest downward tilt (-16 degrees). The uptrend is from the 16 degree upslope to the -2 degrees downslope. Then, as the

downslope increases, a reverse trend of decreasing angle is observed up to the largest downslope. The biggest difference is 15 degrees between slopes of 16 degrees and -2 degrees. At the moment of damping at the different slopes, the change in the angles at the hip joint is the largest. The difference between the 12 degree slope and the -8 degree slope is 27 degrees. The smallest are the degrees in the upward slopes 16; 14; 12 degrees, after which they essentially increase linearly to the 0 degree slope. And with all downslopes, the angles at the hip joint are about 160 degrees.

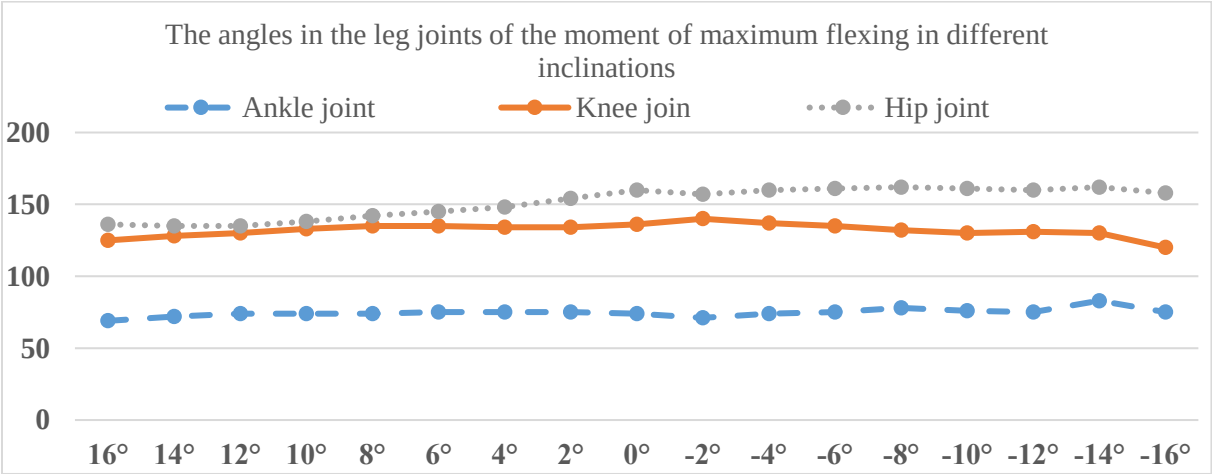

Figure 2. The abscissa shows the values of the angles in the ankle joint, knee joint and hip joint at the moment of maximum flexing at the different slopes of the track**.**

The results of the study of the angles of the ankle joint, knee joint and hip joint at the moment of separation from the support are presented in **Table 3.**

Table 3. *Average values of the angles in the joints of the legs at the moment of separation from the support.*

Moment of separation from the support			
Degrees / Percentages of Inclination	Ankle joint	Knee joint	Hip joint
16° / 28,6%	110°	160°	158°
14° / 24,9%	112°	160°	169°
12° / 21,2%	115°	162°	175°
10° / 17,6%	115°	164°	176°
8° / 14,0%	115°	165°	178°
6° / 10.5%	118°	168°	184°
4° / 6,9 %	120°	170°	191°
2° / 3,4%	122°	174°	210°
0° / 0%	130°	178°	207°
-2° / -3,4%	130°	168°	209°
-4° / -6,9 %	129°	165°	210°
-6°/ -10.5%	125°	163°	206°
-8° / -14,0%	120°	160°	201°
-10° / -17,6%	118°	145°	186°
-12° / -21,2%	115°	133°	170°
-14°/ -24,9%	114°	130°	165°
-16°/ -28,6%	110°	104	161°

Figure 3 shows that the angles in the joints of the lower limbs at the moment of separation from the support at different running slopes change significantly. The study found that in all three joints, the slopes were the smallest during the most pronounced up and down slopes, and the largest during flat and small up and down slopes. The results show that the smallest change in the angles is in the ankle joint, where there is an almost linear increase in the angle with the decrease of the slope and during the uphill and downhill running. The largest difference between the angles at the different slopes is 20 degrees. A similar trend of increasing angles when the slope of uphill running decreases is also present in the knee joint, but in downhill running this trend is much more pronounced. Here, the angle difference between running flat and running down a -16 degree slope is 74 degrees. The angles of the hip joint increase as the slopes decrease from 16 to 2 degrees, the difference being 52 degrees, reaching 210 degrees. These highs are maintained until the run down to -6 degrees. A marked decrease in hip angles follows as the downhill slope increases.

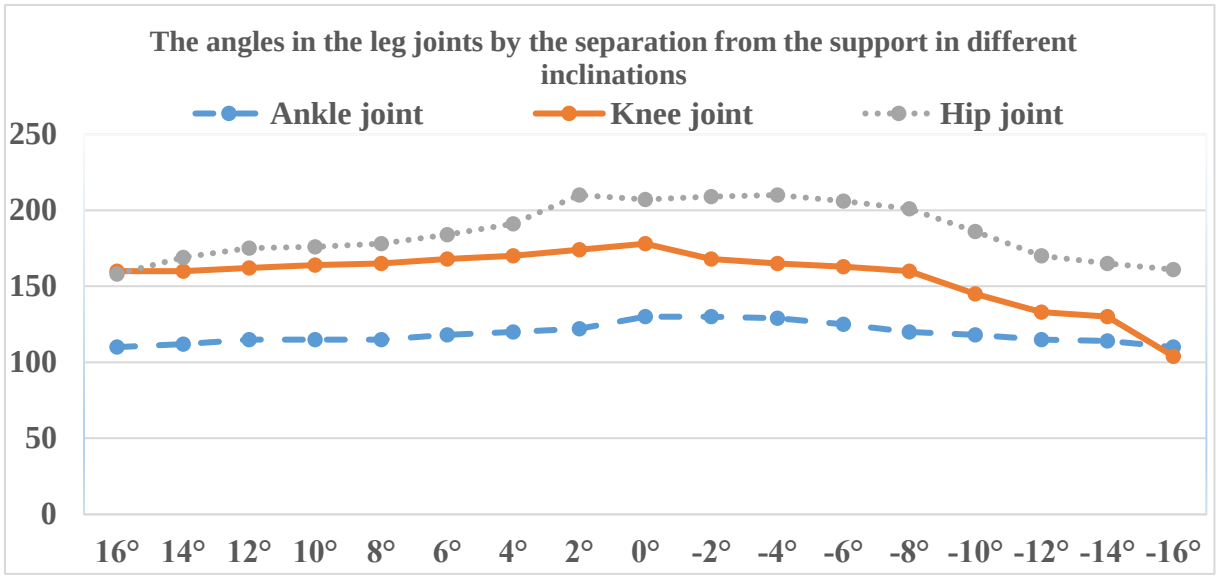

Figure 3. The values of the angles in the ankle joint, knee joint and hip joint at the moment of separation from the support are shown on the abscissa at the different slopes of the route.

CONCLUSION

1. In running on slopes of different steepness at the moment of touching the support, the angle in the ankle joint decreases as the slopes increase.
2. At the moment of touching the support at the different inclinations, the greatest change in angles is found at the knee joint, and the smallest change is at the ankle joint.
3. At the moment of maximum flexing, there is no great change in the angle of the ankle and knee joint at the different slopes, but in the hip joint there is a significant decrease in the angle when increasing the slope of running uphill.
4. At the moment of separation from the support in all three joints, the angles are the smallest in the most pronounced up and down slopes, and the largest angles in the joints in the runs on the level and with a small up and down slope, as the least is the change in angles in the ankle joint.
5. As the inclines of running uphill increase, the angles in all three joints of the lower limbs decrease.
6. In general, during the runs on the different downhill slopes, at the moment of touching the support and the moment of maximum flexing, there are no large changes in the joint angles, while at the moment of separation from the support, the joint angles decrease significantly with the increase of the running slope down.
7. At all three moments of the support period (touching the support; maximum flexing; separation from the support) at the different running slopes, the least change of angles is observed in the ankle joint.

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