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Procedia Engineering 13 (2011) 4–9

Engineering Procedia

5th Asia-Pacific Congress on Sports Technology (APCST)

Classical style constructed roller skis and grip functionality

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Received 18 March 2011; revised 30 April 2011; accepted 1 May 2011

Abstract

Roller skis are used by cross-country skiers for snow-free training, with the aim of imitating skiing on snow. The roller skis on the market that are constructed for use in the classical style are equipped with a front and a back wheel, one of which has a ratchet to enable it to grip the surface when diagonal striding and kick double poling. A new type of roller ski was constructed with a function which makes it necessary to use the same kick technique as that used on snow, i.e. the ski has a camber that must be pushed down to obtain grip. Its stiffness can be adjusted based on factors that influence grip, i.e. the skier's bodyweight and technical skiing skills. Thus, our aim was to make comparative measurements as regards grip between ratcheted roller skis and the roller ski with a camber and compare with previous published results for grip waxed skis during cross-country skiing on snow. The measurements were carried out using specially developed equipment, with a bottom plate and an overlying rubber mat of the same type as used on many treadmills and a function for applying different loads and generating traction on the back of the roller ski.

Keywords: Roller skis; classical style; grip; ratchet; camber; static friction coefficient

1. Introduction

Classical style constructed cross-country skis static friction coefficients (μ_S), defined as the ratio between the tangential and normal forces acting on the ski when it is stationary on the snow, just before it starts gliding, have been studied using force plate systems attached to the skis [1] and by using a long force platform system mounted under the snow [2-4]. As a result, μ_S of 0.04 to 0.15 have been reported, estimated from tangential and normal forces of 0.1 to 0.2 and 1 to 3 times bodyweight, respectively [1-4].

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doi:10.1016/j.proeng.2011.05.043

With the aim of imitating skiing on snow, cross-country skiers use roller skis for their snow-free training. Roller skis on the market, that are intended for use in the classical style, have a construction where one of the two wheels (one wheel at the front and one at the back) has a ratchet that allows a grip on the surface during a leg kick. Since the ratcheted mechanism is not dependent on a load applied to the roller ski, it is likely that this type of construction in practice provides a high μ_S between the ratcheted wheel and the surface, independently of the skier's bodyweight and technical skiing skill. In such a case, this would be in great contrast to skiing on snow on groomed trails where a proper technique is essential to obtain a sufficient grip.

Thus, the purpose of this study was to investigate μ_S of ratcheted roller skis and compare the results to μ_S reported from skiing on snow. Additionally, a different roller ski construction with a camber construction that must be pushed down to obtain grip, was evaluated.

Nomenclature

F	vertical load on roller ski
m	total mass from roller ski, ski binding and aluminium sole
g	acceleration of gravity
N_f	normal force on the forward wheel
N_r	normal force on the rear wheel
S', S	force registered in the load cell
F_l	resisting force of the load wheel
F_f	resisting force of the forward wheel
F_r	resisting force of the rear wheel
F_a	resisting force from the ratcheted spool
h	vertical distance between the rubber mat and the load cell traction point
l_1	distance between the axis of the forward and rear wheel
l_2	distance between the axis of the forward wheel and the vertical load
l_3	distance between the axis of the forward wheel and the centre of mass

2. Methods

2.1. Equipment

The study used four classical style constructed rollers skis (PRO-SKI C2, Sterners, Dala-Järna, Sweden), procured from the open market, described in an earlier paper [5]. The roller skis were equipped with a forward and a rear wheel, where the latter contained a ratchet to enable for grip towards the surface.

Also, a different type of roller ski construction with a camber and adjustable grip function was tested (SportsTech roller ski, Mid Sweden University, Östersund, Sweden). The functionality for this was applied to the forward wheel of the roller ski, see Fig 1. When sufficient load was exerted to press down the camber, the forward wheel established contact with a ratcheted spool (F_a, Ø 20 mm, aluminium, cross lettering size 1.6) situated above the forward wheel. The degree of grip was therefore depending on the stiffness of the roller ski's camber, which was simply adjusted via a spring-loaded screw (SF-TFX 2691, Lesjöfors Stockolms Fjäder AB), and the amount of load put on top of the roller ski (normal force on the forward wheel). This construction used wheels of the same type as the non ratcheted (forward) wheel of PRO-SKI C2.

The roller skis were equipped with ski bindings (Salomon Equipe or Rottefella R3 Classic) mounted with the ski boot fix point at the roller ski centre of mass. The total weight of a roller ski with ski binding and a flat aluminium sole, mounted at the ski boot fix point, was 1.5 kg (PRO-SKI) and 1.8 kg (SPORTSTECH) and the length between the axes of the forward and rear wheel was 722 mm for both types of roller skis.

The μ_S was measured with the roller skis mounted in a fixture specially produced to measure ski characteristics on ordinary cross-country skis [6]. The fixture was supplemented with an applicable bottom plate with an overlying rubber mat of the same type as used on treadmills of a known manufacturer (Rodby Innovation AB, Vänge, Sweden) and a function for applying different loads normal to the surface (F) and generating tangential traction of the roller ski (S´), see Figure 1. To minimize the influence of resisting force from the vertical load (F_l), the bar was equipped with a stainless steel ball bearing wheel which was able to roll on the flat sole. Further, the sole was vertically adjustable at the rear part, as well as the tangential traction point, to allow for level adjustments due to different loads and constructions of the tested roller skis (h).

2.2. Mechanics of the roller skis

There is a schematic sketch of the experimental setup in the free-body diagram in Figure 1.

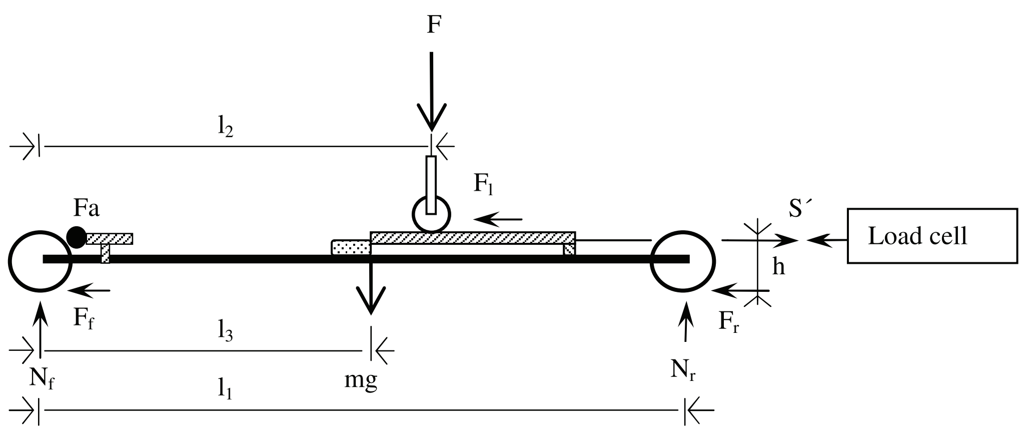

Fig. 1 Free body diagram of the experimental setup.

Horizontal equilibrium, when measured without any contact between the ratcheted spool (F_a) and the forward wheel, shows that:

$$S - F_f - F_r - F_l = 0 \quad (1)$$

In the situation when the ratcheted spool (F_a) is pushed against the forward wheel the force registered in the load cell (S´) gives the equation:

$$S' = F_f + F_r + F_l + F_a \quad (2)$$

With the static friction coefficient (μ_S) defined as the ratio of the resisting force to the normal force (N) on the wheel with the grip function (N_f or N_r), the following relationship was established:

$$\mu_S = \frac{S' - S}{N} \quad (3)$$

The individual normal forces of the forward (N_f) and rear (N_r) wheel were calculated as:

$$N_f = \frac{mg(l_1 - l_3) + F(l_1 - l_2) - S' \cdot h}{l_1} \quad (4)$$

And

$$N_r = \frac{mg \cdot l_3 + F \cdot l_2 + S' \cdot h}{l_1} \quad (5)$$

2.3. Experiments

The roller skis static friction coefficients (μ_S) was studied as a function of different vertical loads and normal forces acting on the wheel with the grip functionality. Masses within the range of 60 to 100 kg, in a 10 kg interval, was put on top of the sole on the roller ski, 100 mm behind the ski boot fix point. Together with the mass of the tested roller ski, this corresponded to the total normal forces of 603.3 to 995.7 (PRO-SKI) and 606.3 to 998.7 Newton [N] (SportsTech). The length (l_2) between the axis of the forward wheel and the vertical load put on top of the roller ski was 480 mm (PRO-SKI) and 410 mm (SportsTech).

Before starting the measurements with the SportsTech roller ski, the camber was adjusted so that the ratcheted spool (F_a) and the forward wheel merely established contact on the initial measuring load (606.3 [N]), after which the camber was no more adjusted.

Further, the tangential forces derived from the sum of the resisting forces (S) of the vertical stainless steel ball bearing wheel and the forward and rear wheel of the roller skis was measured using the same loads as above and finally subtracted from the results on μ_s, see equations (1-3). For the PRO-SKI roller skis the measurements of S was executed by turning the ratcheted (rear) wheel to grip and roll, respectively, the opposite way and for the SportsTech roller ski without any contact between the ratcheted spool (F_a) and the forward wheel.

3. Results and Discussion

The results of the measurements on μ_s for the two types of classical style constructed roller skis are presented in Table 1 and Figure 2.

Table 1. Results of static friction coefficients (μ_s) for the PRO-SKI and SPORTSTECH roller ski. N_r and N_f are values for the normal forces acting on the wheel with the grip functionality.

Vertical load (F)	588.6	686.7	784.8	882.9	981.0
PRO-SKI					
N_r	426.3	492.7	560.4	627.4	693.9
μ_s	0.93	0.86	0.84	0.81	0.78
SPORTSTECH					
N_f	192.0	218.0	242.9	269.3	295.6
μ_s	0.042	0.293	0.548	0.698	0.829

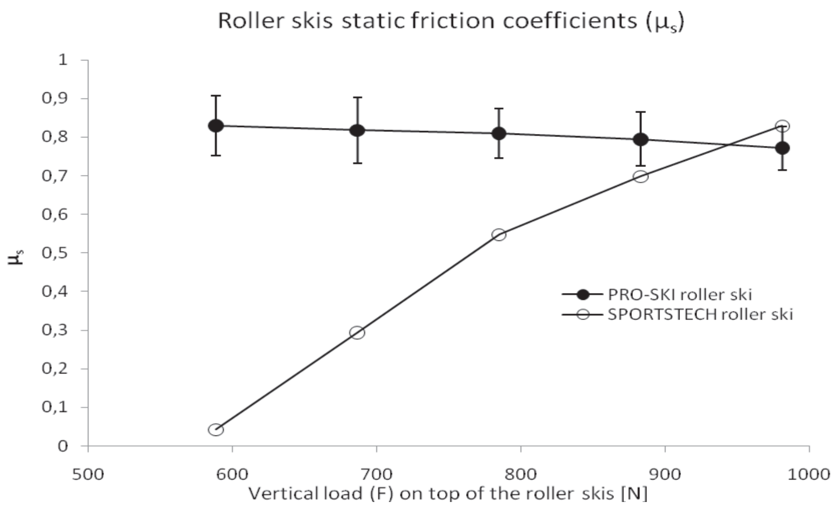

Fig. 2. The figure illustrates the static friction coefficients (μ_s) for the two types of classical style constructed roller skis (PRO-SKI, mean ± SD, and SPORTSTECH roller ski).

The results in this study shows that ratcheted wheel constructed PRO-SKI roller skis, within the vertical loads 600 to 1000 [N], have μ_s around 0.8, which is more than 5 times the values reported from on-snow skiing with grip waxed cross-country skis [1-4].

The results for the tested SPORTSTECH camber roller ski showed that μ_s changed from merely nothing up to the level of the tested PRO-SKI.

Thus, one problem with ratcheted wheel constructed roller skis is that this mechanism provides a secure grip even when skiing with a poorly performed technique. This is in great contrast to skiing on snow on groomed trails, where proper technique is essential for good grip. Training with the roller skis that are currently on the market can thus entail that the wrong kick technique is learned, and that there is no opportunity to learn the correct kick during snow-free training. Additionally, much of the current sports research into the physiology and biomechanics of cross-country skiing is conducted on treadmills using ratcheted roller skis, which would not appear to be optimal.

The measurements in this study were made on a rubber mat of the same type as used on many treadmills, while most of the training sessions, performed by cross-country skiers, probably are carried out on asphalt surfaces. Thus, how outdoor environment and surfaces affect μ_s of ratcheted wheel constructed roller skis is not investigated in this study. However, during normal weather conditions, it is not likely that μ_s on asphalt surfaces strongly deviate from the results in this study.

Different manufacturers use different types of material for the roller ski wheels (rubber, thermoplastic polyurethane) and, also, choose to mount the ratcheted wheel either in the rear or in the front position. Depending on the position, this will affect the normal force of the ratcheted wheel and may thus have some influence on μ_s.

Thus, an enlarged study of μs is needed, involving different roller ski manufacturers with alternative positions for the ratcheted wheel. Also, more of the SportsTech roller skis need to be measured in order to establish mean and SD values for this type of construction.

Following this, an integrated biomechanical and physiological study for comparisons between roller skiing, involving both types of classical style constructed roller skis, and cross-country skiing on snow.

4. Conclusion

The results of this study showed that ratcheted wheel constructed roller skis reached values of μ_s which were five times more than the values reported from on-snow skiing with grip waxed cross-country skis, while μ_s of the tested camber roller ski varied from zero up to the level of the tested ratcheted roller skis.

Acknowledgements

Thanks are due to the European Union's regional development fund, which provided financial support for the study.

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