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IS IT STILL IMPORTANT TO BE LIGHT IN SKI JUMPING?

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SUMMARY

In ski jumping low body weight development resulted in some serious underweight problems and therefore International Ski Federation (FIS) decided to solve the problem by relating maximum ski length to Body Mass Index (BMI). The present study examined the current relationship between body weight (BMI), ski length and performance (jumping distance) in ski jumping. The computer simulation showed that BMI regulation adopted by FIS for ski jumping in 2004 has reduced the effect of body weight on jumping distance, but despite use of shorter skis it is still advantageous to be light within certain limits.

INTRODUCTION

The importance of being light is well known in sport events in which gravitational factors restrict performance. In ski jumping low body weight development resulted in some serious underweight problems and therefore International Ski Federation (FIS) decided to solve the problem by relating maximum ski length to Body Mass Index (BMI). It was believed that it would no longer be attractive to be underweight. Body composition problems in ski jumping have been studied comprehensively by Müller [e.g. 1, 2, 3] and Schmöltzer and Müller [4, 5]. According to Müller the mean BMI decreased from 23.6 kg/m^2 in 1970-75 to 19.4 kg/m^2 in 2002, and the most extreme values were as low as 16.4 kg/m^2. This change corresponds to 13.6 kg in body weight of 1.80 m ski jumper.

At this moment (since 2011) maximum ski length for men and ladies is 145 % of body height provided that jumper's BMI is 21. For athletes with less than this minimum BMI a grading table of 0.125 BMI per 0.5 % reduction of ski length is applied. Weight is measured with suit and boots which means that 21 corresponds to a correctly measured BMI of around 20. The FIS cut-off point was originally set to match WHO underweight value 18.5 and thereafter it has been changed a couple of times because of unwanted results in jumpers' body composition. This is not a surprise as body weight is very important performance factor affecting the jumping distance in ski jumping (Figure 1) and most likely the ski length reduction has not appeared to defeat the advantage of low body weight. In the World Cup season 2011-12 the average height of 50 best jumpers were 178.2 ± 5.1 cm and the average range of weight and BMI were 65.4 ± 4.4 kg – 66.5 ± 4.5 kg and 20.5 ± 0.5 – 20.9 ± 0.6 kg/m^2, respectively. 29 of those 50 jumpers had BMI lower than 21 during the entire season and only eight jumpers used maximum ski length.

This paper examines the current relationship between body weight (BMI), ski length and performance (jumping distance) in ski jumping. The final result is much dependent on the BMI-induced change in aerodynamic force opposite to gravitation and take-off force (Figure 2).

METHODS

The computer simulator used in the present study is a time-discrete second-order-CoG-point simulator modeling the complete ski jumping performance: the in-run, take-off, transition to flight and flight. The following parameters were used as input information: Total mass and reference area of a ski jumper (based on jumper's anthropometrics) including skis, air density, coefficient of ski friction, take-off force profile, drag (C_d) and lift (C_l) coefficients for the crouch inrun position, and $C_d(t)$ and $C_l(t)$ for the flight phase. The hill profile used in this study represents the modern large hill construction (Klingenthal HS-140 m, FIS certificate No. 55/GER 44).

The simulations were done for two different jumpers with different body size (184 cm and 173 cm). BMI 21 with maximum ski length 145 % of jumpers' body height was used for reference jumps of these two jumpers: 130 m and 134 m, respectively. The official BMI table of FIS was then used to simulate the effect of ski length reduction (143, 141, 139, 137 and 135 %) on jumping distance. This "sensitivity analysis" was done by keeping all other parameters except inrun speed same (see the value of perpendicular take-off velocity, v_p for reference jump of 134 m in figure 2).

RESULTS AND DISCUSSION

Table 1 shows the detailed results of simulations for two jumpers. The effect of BMI regulation on jumping distance of the reference jump 134.0 m is highlighted in figure 1. It can be seen that ski length reduction has not fully defeated the advantage of low body weight. The difference in jumping distance is about 1 m per every 0.5 BMI units below 21. This may be of importance in a very tight competition where the margins are often very small. Ski length reduction alone (e.g. 145 > 135 %) without reduced body weight shortened the reference jumps about 3.5 meters.

It has been said [2] that low weight can cause severe performance setbacks including decreased jumping power. However, it is good to remember that reduced body weight, per se, requires less take-off power for certain perpendicular take-off velocity, v_p. With typical force-time characteristics of ski jumpers' take-off an advantage of 3.1 m between BMI 21 and 19.5 (4.5 kg in body mass of jumper B) will be obtained by 7.1 % less average force production due to lower body weight. This advantage is lost if v_p is decreased 7.2 % which corresponds to decrease of 7.4 % in the average take-off force. Thus the advantage of 3.1 m is lost if the average force production is decreased by 14 % corresponding to equivalent jumping height of 0.055 m.

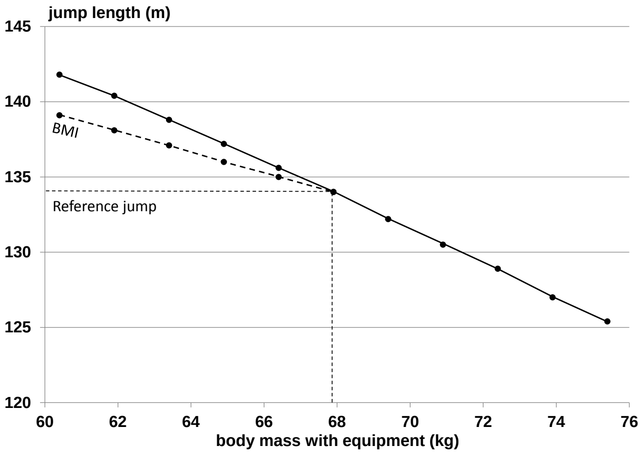

Figure 1: Relationship between body mass and jumping distance without (solid line) and with (dashed line) BMI regulation (shorter skis and lower body weight) for BMI values of 21 (reference jump 134 m), 20.5, 20.0, 19.5, 19.0 and 18.5.

By adopting the BMI regulation to specifications for competition equipment, FIS succeeded in stopping the alarming development of underweight problems in ski jumping.

CONCLUSIONS

This parametric study suggests that the weight of the jumper is more sensitive factor to jump length than ski area (ski length). In fact, sensitivity analysis shows that reducing BMI by 1 % requires a reduction of approximately 1.6 % in ski area to compensate each other. The ski area represents only about half of the total aerodynamic area and thus 10 % change in ski length produces only 5 % change in aerodynamic forces. It is not known if there is a threshold limit in ski length below which it becomes technically very difficult to jump with very short skis although theoretical simulation still provides an advantage.

Müller [2] has suggested 2009 that an increase of the BMI border line value would enlarge the pool of possible winners as the number of competing ski jumpers could increase. However, as the underweight problems seem to be solved from a health point of view, and, because low body weight will always be an "issue" in ski jumping, there should be no further need to increase BMI.

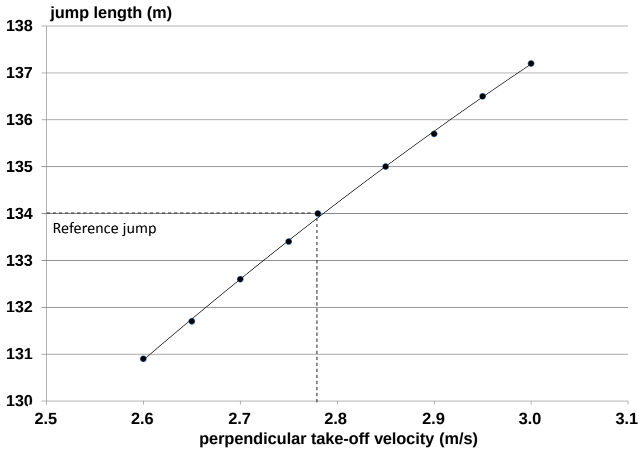

Figure 2: Effect of perpendicular take-off velocity on jumping distance (jumper B).

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Table 1: Simulation results for two jumpers with different body height. BMI, body mass and ski length are from FIS specifications for competition equipment (edition 2012/2013).

Jumper A 184 cm					**Jumper B 173 cm**			
BMI	**body mass (kg)**	**ski length (cm)**	**jump distance (m)**	**inrun speed (km/h)**	**body mass (kg)**	**ski length (cm)**	**jump distance (m)**	**inrun speed (km/h)**
21.0	**71.1**	**267**	**130.0**	**91.77**	**62.9**	**251**	**134.0**	**91.08**
20.5	**69.4**	**263**	**131.4**	**91.71**	**61.4**	**247**	**135.0**	**90.93**
20.0	**67.7**	**259**	**132.5**	**91.65**	**59.9**	**244**	**136.0**	**91.00**
19.5	**66.0**	**256**	**133.7**	**91.59**	**58.4**	**240**	**137.1**	**90.85**
19.0	**64.3**	**252**	**135.1**	**91.52**	**56.9**	**237**	**138.1**	**90.77**
18.5	**62.6**	**248**	**136.3**	**91.45**	**55.4**	**234**	**139.1**	**90.68**

*FIS uses body mass with jumping suit and boots.