Pilot Study for the Evaluation of Thermal Properties and Moisture Management on Ski Boots

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Abstract: Winter sports are often performed in severe environmental conditions and this could represent a limit in terms of comfort and therefore performance. Since alpine skiing has the biggest number of practitioners among the winter sports and because the feeling of cold in the feet is one of the most common problem, a testing method has been developed to perform outdoor tests on ski boots in order to evaluate the thermal comfort for different liner materials. The tests, performed on both male and female skiers wearing the same shell with different liners simultaneously (one on the left foot and one on the right foot), showed that a significant difference in terms of comfort using different liners in the same environmental conditions is present. Specific tests have been made to ensure that such differences between the two feet were not due to physiological difference between left to right feet; for this reason, data has been recorded using the same shell and liner for both feet, obtaining negligible differences between the two. Moreover, the collected data can be used to optimize the target of use of the ski boot and liner, choosing the best materials to achieve specific behaviour in terms of heating, breathability and moisture management.

1 INTRODUCTION

Footwear thermal insulation is one of the most important factors for protection against cold. Since hands and feet have a large surface area compared to their volume and a small muscle mass, they both tend to be much more sensitive to cold exposure compared to other parts of the human body (Kuklane, 2009). If it is true that the entire body's thermal insulation affects the local thermal condition and that the local insulation has an effect on the total thermal comfort (Afanasieva, 1972), the feeling of cold discomfort into the feet will dominate in spite of proper clothing on the rest of the body (Kuklane, 2009). The feet are comfortable when the skin temperature is about 33°C and the relative humidity next to the skin is about 60% (Oakley, 1984); (Kuklane, 2009). The cold feeling of feet starts at toe's temperatures around 25°C, while discomfort from cold is noted at temperatures under 20-21°C (Enander et al., 1979); (Goldman and Kampmann, 2007); (Kuklane, 2009). A further decrease of the foot temperature below 20°C is associated with a strong perception of cold (Luczak, 1991); (Goldman and Kampmann, 2007); (Kuklane, 2009).

Moisture is the most important variable that affects footwear thermal insulation and thus foot comfort (Kuklane, 2009). Nevertheless, it is important to note that no specific human receptor exists for the sensation of humidity (Bertaux et al., 2010). Footwear should be chosen to keep external moisture from entering and to allow internal moisture to leave the footwear (Kuklane, 2009).

The importance of developing new studies on thermal comfort in sport equipment arises from the need to investigate which are the interactions between men, equipment and environment. All men activities can be strongly influenced by the climate and sport activities are not exceptions.

It is well known how the garments, in sport activities with stressful weather conditions, can affect sport performances (Pezzoli et al., 2010; 2011; 2012). The possibility to study directly on the person the benefits of a particular garment represents a new

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frontier in applied research in sport, allowing to determine whether and how it is possible to improve the performance in different climatic conditions.

Winter sports are performed in the coldest and harshest external conditions of all sports and the effect of the external environment in terms of cold is therefore more consistent with respect to summer sports. Alpine skiing has the biggest number of practitioners among the winter sports. Long exposure times to cold temperature are often the norm since the best conditions are present at temperatures below 0°C.

The best thermal feature that a user can expect from a ski boot is to keep him warm and dry, to enjoy a sport day in the outdoors or to perform well in a race. With the right amount of insulation it is possible to keep the feet into the range of comfort and to avoid frostbite; moreover, the heat generated is better trapped in boots with higher insulation (Kuklane, 2009). The insulation properties of shoes and boots are directly proportional to the amount of air trapped inside the fabric and between the foot and the shoe, but when this space is filled by moisture, the insulation loses its effectiveness. The use of thicker socks could increase the overall insulation but if the thickness it too high, it could subtract space to the foot inside the boot, creating problems to the blood circulation.

Another critical element among the characteristics of a boot is its ability to expel moisture from the inside to the outside; this feature is usually called breathability. A different way to expel moisture is called “pumping effect” and it takes place during walking. In ordinary shoes the pumping effect can remove about 40% of humidity (Gran, 1957); (Kuklane, 2009). On the contrary, for ski boots these considerations are not applicable. In fact, it has been well demonstrated that in cold conditions (sub-zero temperatures), the evaporation due to the pumping effect and evaporation in general are usually less than 5% (Kuklane and Holmér, 1998); (Kuklane et al., 1999; 2000); (Rintamäki and Hassi, 1989). Moreover, ski boot shells are made of impermeable plastics such as polyurethane, polyolefin and polyamide. Impermeable materials do not allow moisture from the outside to enter and wet the insulation layers but, at the same time, almost all the moisture generated during the sport activity condenses inside the boot. Finally, the physical activity, especially during sport performance can affect the amount of moisture and this can strongly influence foot temperatures. Some of the latest studies have demonstrated that a foot can sweat about 30 g/h and in some cases even up to 50 g/h (Taylor et al., 2006); (Fogarty et al., 2007); (Kuklane, 2009).

Therefore, the properties of the inner boot (in terms of insulation and moisture management) become dramatically important.

For all the reasons reported above it is clear the need of a method for testing and evaluating the thermal comfort on ski boots with different liners.

A pilot study was carried out on a reduced number of testers with the intent to obtain preliminary qualitative and quantitative data to use for the construction a complete measurement protocol. Since the method proposed in this paper can collect data directly from outdoor conditions during real skiing activity, it represents an innovative approach in terms of materials development, which has been instead previously based on climatic chamber simulations (Havenith et al., 2008); (Wang et al., 2012).

2 MATERIALS AND METHODS

Tests have been performed by placing small wireless sensors (Maxim-Dallas, Hygrochron) to record temperature and relative humidity inside the liner and between the liner and the shell (inside the foot-board placed between the liner and the external plastic shell).

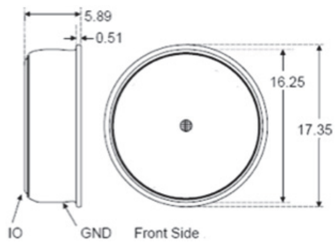

Figure 1: Sensor shape and size [mm].

The sensor dimensions (Figure 1) allow the possibility to position them in the place where the most cold is expected (front part of the boot), without interfering with the skiing action or causing pressures to skier’s feet. Proper slots have been obtained by removing small amounts of material from the sole and the foot-board. For both positions, the most sensitive part of the sensor has been directed towards the foot (sole) and toward the liner’s sole (foot-board). The slots have been externally insulated in order to avoid an increased entrance of cold from the slots.

The relative humidity resolution of the sensor is 0,6% while the temperature resolution is 0,5 °C working with a sampling bit-rate of 8-Bit (recommended for battery saving, especially in cold environment). The data collection was carried out through a software designed for the sensors by the manufacturer, correction for humidity and temperature is handled automatically using the software (typical accuracy is ± 0,5 °C and ± 5 % for relative humidity with software correction). Sensor sampling rate was set to 30 seconds, since this low frequency data acquisition has been considered sufficient to describe the phenomena; the average values are calculated among the data recorded during the ski session (lift sessions included), values are rounded to the first decimal place.

Each boot was equipped with two sensors: one placed on the liner sole (Figure 2) and one on the foot-board (Figure 3). All sensors have been placed in the toe area, considering this as the most critical part. Indeed, it is reported in the literature that the temperature in the toes is lower than that in the whole foot in cold conditions (Kuklane, 2009). On the contrary, in comfort conditions (above 25°C), is easy to have similar temperature levels in toes and the rest of the feet (Kuklane, 2009). Wearing appropriate footwear to protect from the cold, during strong cold sensations, the toe's skin temperature is about 5°C lower than the mean foot skin temperature (Kuklane, 2009).

Figure 2: Sensor placed on the liner sole (SOLE).

Figure 3: Sensor placed on the Foot-board (F-B).

A portable weather station (Skywatch, GEOS 11) has been used in order to validate the results and measure the environmental conditions during the test. The weather station was used to measure the wind speed, air temperature, air relative humidity, altitude and pressure.

An additional on-board sensor (Maxim-Dallas) was used to measure air temperature and relative humidity outside the ski boots for all the duration of the test. The sensor has been installed outside the skier's jacket and, comparing its output with the data from the weather station, it has been verified that the body heating did not affected its records.

Each test session has been performed by comparing simultaneously two types of liners, built with different materials and technology. One liner tested is a traditional liner (Figure 4), made of a mix of preformed ethylene vinyl acetate (EVA) and others foams with the upper layer made of polyethylene (PE) or polyvinyl chloride (PVC) and with the lower sole made of PVC; the other liner tested is a liner fully made of a mix of different density closed cell EVA foam (Figure 5).

Figure 4: Traditional liner.

Figure 5: Liner made of closed cell EVA foam.

For women tests four different liners have been tested:

- Traditional with PVC upper layer and PVC bottom sole.
- Traditional with PE upper layer and PVC bottom sole.
- Traditional with PE upper layer and PVC bottom sole with extra insulation at the tip.
- Full EVA closed cell liner.

Tests have been carried out on the slopes, using both chairlifts (open) and gondolas (closed) simulating a standard ski sessions. Data has been recorded in continuous from 2 to 4 hours for each session depending on the weather conditions; mean values in the following tables have been calculated on an average time of 2 hours. All testers have been interviewed on their perceptions and sensations about the ergonomic and thermal comfort during the tests and at the end of each session. All test have been performed in the Italian Alps: male tests took place in Limone Piemonte (Top: 2085 m; Bottom: 1043 m), female tests took place in Val Gardena (Top: 2453; Bottom: 1200 m).

Four testers have been used:

- TESTER 1 (T1), male, 29 years old, 70 kg, expert skier, (Session S1 – S2)
- TESTER 2 (T2), male, 32 years old, 80 kg, expert skier (Session S3)
- TESTER 3 (T3), male, 29 yeas old, 85 kg, professional skier (Session S4 – S5)
- TESTER 4 (T4), female, 26 years old, 55 kg, professional skier (Session S6 – S7 – S8 – S9).

All testers have used socks that they routinely use during their alpine skiing. All socks used are made of synthetic fibres.

3 RESULTS AND DISCUSSION

3.1 Male Tests

All tests have been performed in winter conditions, in five different sessions.

In the following tables are reported the results obtained for temperature and humidity, measured with the on-board sensor on the skier jacket (AMBIENT), in the foot-board (F-B) and at the sole level (SOLE).

The first test has been performed to measure feet temperature and relative humidity with the same boot setup on both feet (Session 1, Tester 1, traditional liner with PVC upper layer and PVC bottom sole for each ski boot) in order to assess the difference between left and right foot and the reproducibility of the method.

Table 1: Session 1, TEMPERATURE [°C].

	MIN	MAX	AVERAGE
AMBIENT	1,0	13,1	5,2
F-B PVC sx	7,0	8,0	7,4
F-B PVC dx	7,1	8,6	7,5
SOLE PVC sx	14,1	15,6	14,5
SOLE PVC dx	13,1	14,1	13,5

The same average foot-board temperature has been recorded and the sole temperature difference between the feet was 1 °C (Table 1). The humidity values recorded on the foot-board were almost coincident, while only in the sole it is possible to notice a slight difference (Table 2; 2,2 %).

Table 2: Session 1, RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	46,6	91,1	64,6
F-B PVC sx	51,9	56,2	53,9
F-B PVC dx	52,2	55,7	53,8
SOLE PVC sx	96,0	101,2	99,4
SOLE PVC dx	92,5	100,9	97,2

These results show that, even if there could be a difference in terms of temperature and relative humidity between the two feet due to physiological or mechanical causes (e.g. different buckles clamping), these differences are negligible compared to those due to the liner performance, which will be shown in the following.

Graphs that report the temperature and humidity measurements from S1 are shown in Appendix.

The results obtained for temperature and humidity in the second session (S2), which has been a mild winter day (Table 3) are reported in Table 3 and 4.

Table 3: Session 2, TEMPERATURE [°C].

	MIN	MAX	AVERAGE
AMBIENT	-3,5	11,1	1,9
F-B PVC	4,1	14,1	6,4
F-B EVA	5,1	15,6	9,6
SOLE PVC	10,6	28,2	14,5
SOLE EVA	13,1	29,6	21,2

Table 4: Session 2, RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	43,9	97,5	67,3
F-B PVC	50,9	61,9	58,7
F-B EVA	55,1	62,5	58,4
SOLE PVC	86,5	102,3	97,9
SOLE EVA	81,2	112,7	101,5

The testing session day has been characterised by an average temperature which stayed above 0 °C (1,9 °C) with a maximum temperature of 11,1°C (Table 3). In this case there is a substantial difference between the temperatures recorded in the two soles (Table 3). The difference recorded between the two liners (average, 6,7 °C) is well above the difference measured in the first session using the same ski-boot and liner set-up for both feet (average, 1 °C) and therefore it is possible to state that there is a clear difference in thermal insulation between the two liners in these skiing conditions.

The EVA liner, maintaining the average foot temperature above the critical temperature of 20 °C, has been able to offer a greater thermal comfort, in agreement with what was found at the end of the session interviewing the tester about his feelings. Indeed, T1 reported a higher thermal comfort with the EVA liners and a similar ergonomic comfort with both liners.

The average values for the relative humidity inside the liner (Table 4) in both cases have been close or above the saturation limit.

In Table 5 and 6 are reported the results obtained for temperature and humidity in the third session (S3), which has been a much more colder winter day with respect to S2.

Table 5: Session 3, TEMPERATURE [°C].

	MIN	MAX	AVERAGE
AMBIENT	-7,5	2,6	-4,6
F-B PVC	3,1	11,6	7,5
F-B EVA	10,5	14,6	12,4
SOLE PVC	10,1	25,6	17,3
SOLE EVA	23,1	29,6	26,9

Table 6: Session 3, RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	35,9	65,9	52,5
F-B PVC	42,3	53,7	50,5
F-B EVA	42,2	54,9	48,3
SOLE PVC	96,3	106,9	103,2
SOLE EVA	74,3	107,8	96,6

The whole test was conducted with an average temperature which has been constantly below 0 °C. As for S2 (Table 3), it is interesting to notice that inside the liner, next to the toe (sole temperature), the PVC liner has had an average temperature which stayed in the discomfort range (Table 5; 17,3 °C), while the EVA one offered enough comfort (Table 5; 26,9 °C), especially when compared to the extreme cold conditions recorded.

Also the foot-board in the system equipped with the EVA liner showed higher temperature values. However, the temperature difference in the foot-boards (with the two different liners) is lower if compared to the difference of the temperature measured in the sole for the same couple of liners. For this reason, as expected, the sensor positioned in the sole can show more significant differences in terms of insulation behaviour for different liners with respect to that positioned in the foot-board. The sensor positioned in the foot-board should give instead good information on the insulation behaviour of the shell, if tests with different type of plastic shells are performed. Indeed, the temperature in the foot-board was always comprised between the external temperature and the sole temperature, indicating that the shell has a real thermal insulation. Moreover, the thermal fluctuation between the maximum and the minimum temperature record is always less intense in the foot-board with respect to the sole and to the external temperature, again indicating an insulating behaviour of the shell.

The average relative humidity (Table 6) of the EVA liner stayed below 100% while the PVC one passed the saturation limit (103,2 %), indicating that the foot was wet.

The tester reported a higher thermal comfort with the EVA system despite a higher ergonomic comfort with the PVC liner.

The results confirmed the tendency of the EVA liner to be warmer compared to the PVC one. Maximum difference between the two, during session 1 and session 2, can be calculated from Table 5 (9,6 °C) and from Table 3 (6.7 °C) indicating that the external conditions have an effect on the temperature difference between the two liners and in particular that in very cold environments (below -10°C) the difference between the liners will be larger.

In Table 7 and 8 are reported the results obtained for temperature and humidity in the fourth session, which is the first of two sessions (S4 - S5) carried out with tester 3. These tests have been performed in order to maintain the same tester and to perform two different skiing activities (free-skiing and slalom racing).

In tables 7 and 8 are reported the results obtained for temperature and humidity, measured with the on-board sensor (AMBIENT) and at the sole level (SOLE) for the comparison between PVC liner and full EVA one during a free skiing session with no gates.

Table 7: Session 4, TEMPERATURE [°C].

	MIN	MAX	AVERAGE
AMBIENT	5,0	10,0	7,6
SOLE PVC	13,5	16,0	14,9
SOLE EVA	14,5	17,1	15,9

Table 8: Session 4, RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	27,6	48,0	36,7
SOLE PVC	93,5	100,5	97,2
SOLE EVA	91,1	99,6	95,2

In Table 9 and 10 are reported the results obtained for temperature and humidity in the fifth session, which is the second (S5) carried out with T3, this time in a slalom racing skiing activity.

Table 9: Session 5, TEMPERATURE [°C].

	MIN	MAX	AVERAGE
AMBIENT	5,6	12,2	8,2
SOLE PVC	20,6	27,6	23,4
SOLE EVA	24,6	28,1	25,8

Table 10: Session 5, RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	26,5	39,8	33,5
SOLE PVC	99,1	103,8	101,6
SOLE EVA	94,5	99,9	97,6

Both sessions of tests have been carried out in similar conditions of temperature (Table 7 and Table 9) and humidity (Table 8 and Table 10). In both cases the EVA liner has recorded higher sole temperature values compared to the PVC one; but during S4 both average temperatures (PVC and EVA) have been very low (Table 7) while in session 5 they have been both closer to the comfort area (Table 9).

This difference can be ascribed to the different physical effort made by T3 between the two sessions. Indeed, S4 has been a free skiing session while S5 has been characterized by a racing ski slalom session using gates that requires more effort with respect to a free skiing activity.

The higher physical effort in S5 is also responsible of the higher humidity values (Table 10) compared to S4 (Table 8). Therefore, it is clear the effect of the type of skiing performed and for this reason it is not possible to make comparison between different sessions unless a controlled skiing is performed (same terrain, same length of the run, same skiing approach and speed). Nevertheless, the use of two different skiing styles does not affect the relative behaviour of the two liners: in both sessions (S4 and S5) a similar trend was observed since in both cases the full EVA liner was warmer compared to the PVC liner (average difference 1°C in session 4 and 2,4 °C in session 5).

3.2 Female Tests

All four sessions have been performed in winter, using four types of liners. Similarly to what has been done for men tests, for each session, the trend of environmental parameters for the entire duration of the test has been recorded and analysed. The following results have been recorded testing ski boots with a professional skier, female, 26 years old (T4).

In the following tables are reported the results obtained for temperature and humidity, measured with the on-board temperature (AMBIENT), and at sole level (SOLE).

- Table 11, Table 12 (PE vs. PE + tip extra insulation)
- Table 13, Table 14 (PVC vs. PE + tip extra insulation)
- Table 15, Table 16 (PVC vs. full EVA)
- Table 17, Table 18 (PE vs. full EVA)

Table 11: Session 6 - PE vs. PE + tip insulation TEMPERATURE [°C].

	MIN	MAX	AVERAGE
AMBIENT	-5,5	12,6	1,7
SOLE PE	17,6	28,1	20,7
SOLE PE + tip extra insulation	17,6	28,6	21,8

Table 12: Session 6 - PE vs. PE + tip insulation RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	35,2	86,3	66,4
SOLE PE	94,1	113,3	103,5
SOLE PE + tip extra insulation	75,6	102,4	99,3

The average temperatures of the sole (Table 11) show that, under the conditions in which S6 took place, the extra insulation on the toe of the shoe ensures a slightly improved thermal comfort. Furthermore, the different type of material used for the tip insulation seems to give the footwear a higher breathability, due to the lower relative humidity, especially with reference to the minimum and maximum values (Table 12).

Table 13: Session 7 - PVC vs. PE + tip insulation TEMPERATURE [°C].

	MIN	MAX	AVERAGE
AMBIENT	-4,0	-0,4	-2,7
SOLE PVC	13,6	17,6	15,3
SOLE PE + tip extra insulation	11,6	16,1	13,4

Table 14: Session 7 - PVC vs. PE + tip insulation RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	77,8	103,7	95,8
SOLE PVC	100,1	102,9	101,2
SOLE PE + tip extra insulation	95,6	103,1	100,1

A rather cold climate and short snow showers have characterized this second test made by T4 (session 7). In these conditions the PVC liner was warmer compared to the PE with extra insulation liner but none of the two shoes tested has allowed the athlete to maintain the temperature of the feet within the comfort levels (Table 13; both < 20 °C). The relative humidity was very high in both cases (Table 14).

Table 15: Session 8 - PVC vs. full EVA [°C].

	MIN	MAX	AVERAGE
AMBIENT	0,5	11,5	4,7
SOLE PVC	17,6	29,6	22,9
SOLE EVA	17,6	30,6	22,5

Table 16: Session 8 - PVC vs. full EVA RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	53,2	91,32	74,0
SOLE PVC	84,6	110,8	103,2
SOLE EVA	92,5	106,8	101,5

S8 has been carried out in a winter sunny day with high average temperature (4,7 °C; Table 15); moreover, the aspect of the slopes and the solar radiation should have emphasized the feeling of comfort. In fact, both liners behaved in a similar manner, ensuring enough thermal comfort at the tip of the foot (Table 15).

Table 17: Session 9 - PE vs. full EVA [°C].

	MIN	MAX	AVERAGE
AMBIENT	-2,5	9,6	1,2
SOLE PE	18,6	26,6	22,8
SOLE EVA	21,1	24,6	22,7

Table 18: Session 9 - PE vs. full EVA RELATIVE HUMIDITY [%].

	MIN	MAX	AVERAGE
AMBIENT	64,1	104,7	94,5
SOLE PE	95,5	104,7	101,0
SOLE EVA	88,5	100,5	95,7

S9 was performed with an average temperature slightly above 0 °C (Table 17; 1,2 °C) and a really high air humidity due to some snow showers (94,5 %). The analysis of the extreme values in table 17 shows that, despite a difference of 2,0 °C for the maximum values (26,6 °C and 24,6 °C), the EVA liner did not crossed the border between the comfort and the feeling of cold; indeed, the minimum temperature recorded in the PE liner is 2,5 °C lower compared to the one in the EVA liner (18,6 °C and 21,1 °C; Table 17). For each liner comparison, the tester's sensation of comfort was in agreement with the data collected by the sensors.

4 CONCLUSIONS

Using this innovative method, it has been possible to measure the performance of the footwear in the real conditions of use, providing detailed information on the thermal comfort for different materials used.

From the perspective of interaction with the human body, taking into account the environmental conditions in which the tests were performed (being those that generally characterize alpine skiing), the EVA liner seems to have superior thermal characteristics for both male and female testers.

As for the temperature, very high differences were found between the different types of liner (Table 5) and significant differences were revealed with the selective use of insulating material in the area of the tip of the foot (Table 11). These differences, even if of the order of a few degrees, can be decisive for the achievement of a sufficient thermal comfort, for a safe sport practice and for the attainment of high performance.

Though with minor differences, the behaviour of the ski boots in moisture management is in line with what expect from a shell completely impermeable to air and water. The ability of the ski boot system to manage the water vapour and its condensation inside the boot represents an important research field for further investigation in the immediate future.

The climate data collected by the weather stations (fixed and portable) and from the additional on-board sensors have been essential to correlate the environmental parameters to the behaviour of different materials used. In fact, the difference in terms of average temperature inside the shoe between EVA liners and traditional ones increases as the ambient temperature decreases (Table 3, Table 5).

While the on-board sensors showed fluctuations synchronous with the typical phases of stop/motion due to the alternation between lift and skiing sessions, the ski boot system seems to be not affected by these alternations, showing no fluctuation in phase with those mentioned above; for this reason it can be argued that, under the conditions in which the tests were conducted, lifts sessions do not represent a particularly critical issue in achieving thermal comfort, though it must be taken into account that they represent quasi-static sessions.

The data collected also show that higher temperatures have been recorded for men testers with respect to those for women; this denotes a greater difficulty in ensuring a good level of thermal comfort for the female gender. For both male and female, further research can be carried out on subjects with different tolerance to cold.

The application of this method to a larger number of testers in a more standardised manner (i.e. using the same skiing exercise pattern, the same duration of each session and the same socks), coupled with a statistical analysis, can assure great improvements in products optimization, for a better sport experience and a higher performance.

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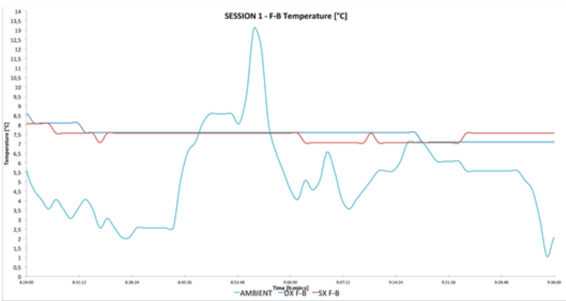
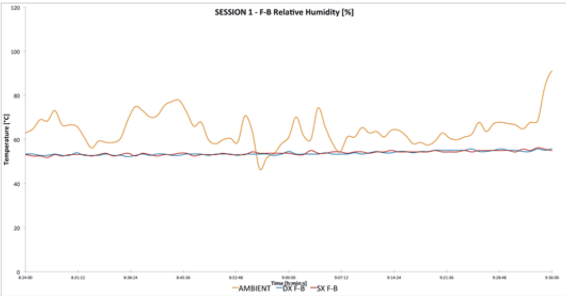
APPENDIX

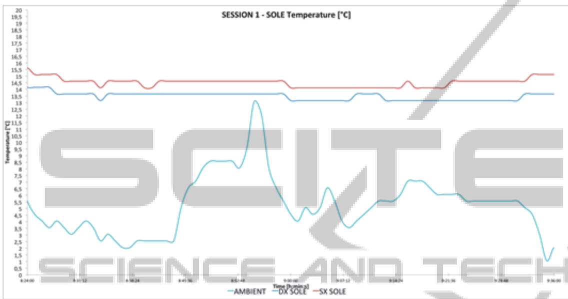
Graph 1: Session 1, F-B TEMPERATURE [°C].



Graph 2: Session 1, F-B RELATIVE HUMIDITY [%].



Graph 3: Session 1, SOLE TEMPERATURE [°C].



Graph 4: Session 1, SOLE RELATIVE HUMIDITY [%].