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Monitoring of the training load and recovery parameters in competitive swimmers

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ABSTRACT

Background Few studies have monitored on a daily basis the training and recovery parameters of competitive athletes over a long period. Possible explanations for this current lack of research are the technical challenges faced in conducting prospective studies with daily monitoring.

Objective To study the illness and injury patterns among young competitive swimmers and to determine if such health problems are linked with training load.

Methods During the first two macrocycles of the swim season 2013-2014 (approximately 6 months), 38 competitive swimmers from 6 swim clubs of the French- and German-speaking regions of Switzerland completed daily monitoring of training and recovery parameters. The athletes used a web platform called "FITSTATS Performance" for this purpose. The monitoring contained amongst other "The Oslo Sports Trauma Research Center questionnaire on health problems", whose results will be analyzed in this paper using descriptive statistical calculations. Additionally, the potential relationship between health problems and training load will be examined using Pearson's correlation coefficient.

Results A total of 241 health problems were reported, including 173 injuries and 68 illnesses. At any given time, 27.0% of the swimmers had a health problem, while 13.2% reported substantial injury.
The shoulder was the most frequently injured region (46.8%), the one which concerned the most swimmers (45.2%) and which had the worst impact in terms of days lost from training (44 days, 29.5% of the total) and severity score (48.4% of the total score). The mean number of shoulder injury per year was 5.2. The respiratory (41.2%) and the digestive (22.1%) systems were the most frequently involved in illness. The mean numbers of respiratory illness per year was between 1.8 and 2.2.
The critical training period regarding injury and illness was the moderate training-load period. Concerning the illnesses, the winter taper period was as critical as the moderate training–load period. There were no significant correlations beetween any of the training load and health parameters.

Conclusion The shoulder is the most commonly injured body part and the respiratory and digestive systems are the most frequently involved in illness in competitive swimmers. However, the respiratory system is not more frequently affected in our swimmers' population than in the general population.
The critical training period regarding injury and illness is the moderate training-load period and not the intensive training-load period. Concerning the illnesses, the winter taper period is as critical as the moderate training–load period. Coaches and swimmers have to be particularly aware of the recovery process during the winter taper period in order to reach the major competition at the top of their fitness. We could not show that health problems, injury or illness, are correlated with training load variation during a six months training period.

KEYWORDS
Training,
Injury, illness, prevention,
Recovery,
Monitoring,
Overtraining,
Swimming,
Online tool.

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CHAPTER ONE

Introduction

During the last years many researchers have taken an interest in ways to monitor elite athletes' training, in order to optimize training effectiveness and simultaneously to preserve the athlete's health (1). One of the most common problems within a suboptimally designed training program is the occurrence of the overtraining syndrome (1, 4). The definition of this syndrome by Kreider et al. (2) is currently accepted by both the "European College of Sport Science" and the "American College of Sports Medicine" (1), and reads:

"*An accumulation of training and/or non-training stress resulting in long-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of maladaptation in which restoration of performance capacity may take several* ***weeks or months****.*"

The current recommendations concerning training monitoring and early detection of the overtraining syndrome advise to carry out psychological monitoring using validated questionnaires (such as the Profile of Mood State (POMS)), a monitoring of the training load perceived by the athlete (e.g. session rating of perceived exertion (RPE)) (5, 6, 7), a health problem monitoring tool (8, 9) and a performance monitoring tool (1, 3, 7).
The blood parameters and hormonal follow-up is not advised because of cost and feasability reasons, and also, because the current scientific literature has not reached consensus about the usefulness of specific biomarkers (1, 7).

In order to achieve such type of training monitoring, the development of easy-to-use electronic tools allows the collection of athlete's data in a standarised manner. Such tools are proposed by the many companied, one of which ("FITSTATS Technologies, Inc" (Mancton, New-Brunswick, Canada)), allowed us to use their web platform FITSTATS Performance. This tool is compatible with PC, Mac, iPhone, Tablet and other Smartphones, which facilitates the ease of data collection from the atheltes. This last point is of most importance, since a lot of similar studies failed due to the lack of user-friendly tools enabling data collection.

To date, few studies have monitored these parameters in a rigorous manner over a long period in competitive athletes (3). Thus, our aim, in this master's thesis, is to identify illness and injury patterns among young swimmers and to determine if such health problems are linked with training load.

CHAPTER TWO

Methods

Recruitment

During the summer 2013, coaches of the main Swiss Swimming clubs were contacted by email. Six clubs were interested in taking part in this prospective study. At the beginning of September 2013, we presented the study to all the swimmers of the six clubs and explained all requirements. They received written information on the study design as well. A total of 38 athletes (19 males and 19 females) ending up giving their informed consent to participate. The trial took place during the first two macrocycles of the season 2013-2014, which started 30.09.2013 till 30.03.2014. March 30^{th} corresponds to the last day of the Long Course Swiss National Championships.
The study was approved on 3^{rd} September 2014. by the Human Research Ethics Committee of the "Canton de Vaud" (Switzerland; study protocol nº 321/13).

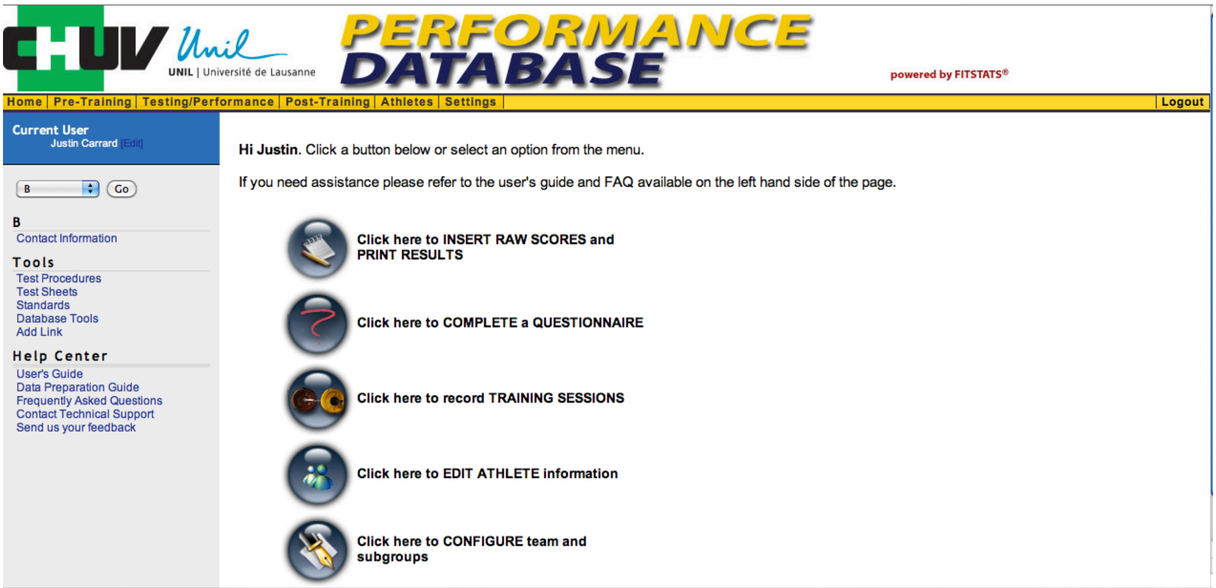
Exclusion and inclusion criteria

All athletes wishing to participate in the study had to be a member of one of the swimming clubs involved in the study.
All these clubs had the quality label "Centre de Promotion des Espoirs" (which means Talent Promotion Centre). This point insures that all the participants had a good competitive level, trained at least about 10 hours a week and were at least 13 years old.
Swimmers were excluded if an overtraining syndrome had been diagnosed during the season 2012-2013 and/or if they had an injury preventing the participation of the training at the start of the study.

Data collection

Throughout the study, the swimmers were asked to enter data in the web platform "FITSTATS Performance", which were obtained and stored anonymously for later analysis. These data include questionnaires, training parameters, time trials during training and competition results. All recorded data and the determined frequency and time at which they were recorded are summarized in Table 2.
Figure 1 shows a print screen capture of the FITSTATS platform.

Figure 1 The web platform Fitstats Performance designed by Fitstats Technologies



Questionnaires

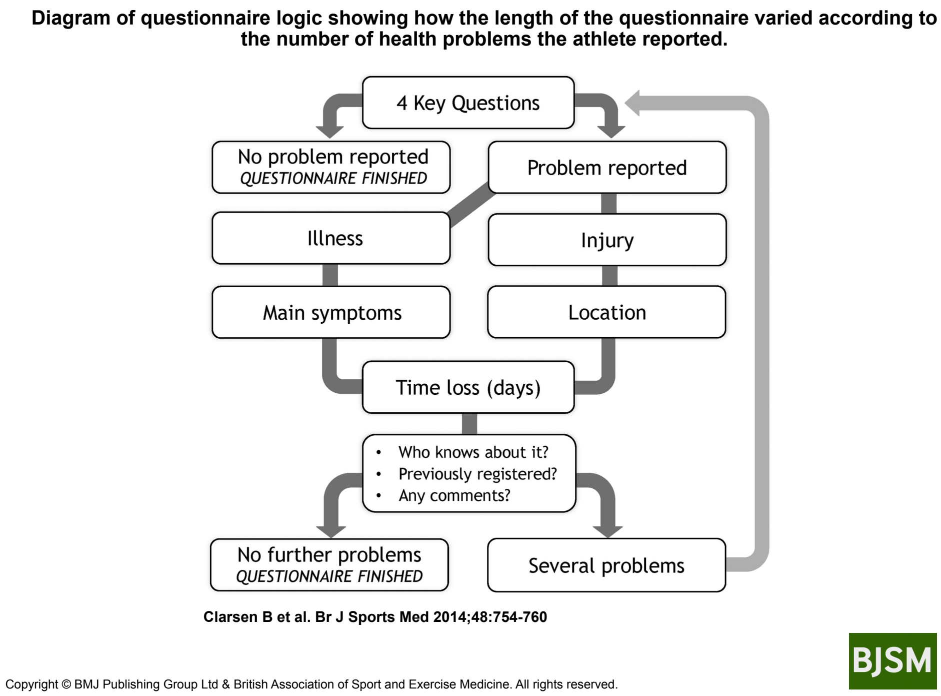
"The Self-Assessment Questionnaire of Recovery Feeling" (appendices 1-3) was elaborated on the basis of similar questionnaires already existing in the web platform FITSTATS.

The principle is the following: the swimmer evaluates twice a week (on Tuesday and Friday) five important components of their recovery, namely the sleep quality and quantity of the previous night, the level of muscle soreness, the level of training enjoyment and the general level of stress (i.e. including the stress outside training). Additionally, the athletes assess their general level of recovery. The six questions use a 7-point scale, where 1 to 3 represent an insufficient level, 4 an acceptable level and 5 to 7 a better than acceptable level of recovery. All of the six questions refer to the lapse of time since the last questionnaire was completed, except for both sleep-related questions, which refer to the previous night.

"The Oslo Sports Trauma Research Center questionnaire on health problems" (hereinbelow "The OSTRC questionnaire on health problems" or "OSLO") was developed by Clarsen et al. (2013) and was used with his permission[8].

The questionnaire (appendices 4-6) had to be slightly adapted to our webplatform, but the functioning remains the same: every Sunday swimmers had to complete the first four key questions. "These concern the consequences of health problems on sports participation, training volume and sports performance as well as the degree to which they have experienced symptoms during the past week. If the athlete answered the minimum score for each of these questions (full participation without problems/ no training reduction/ no performance reduction/ no symptoms) the questionnaire was finished for the week" (8). The athletes only had to check "question not utilized" as answer for the next 8 questions. "In contrast, if they checked anything other than the minimum value for any of the key questions" (8), it means they experienced some health problems in the past week and they were therefore required to complete all other questions. In case they had more than one problem, they had to complete one questionnaire per problem. If they had an injury, they had to indicate which region was injured; and if they had an illness, they had to choose their main symptoms from the proposed list. Finally "for all type of problems, the number of days of complete time loss, defined as the total inability to train or compete, was also registred" (8). Figure 2 shows the principle of this questionnaire.

Figure 2 Diagram of questionnaire logic showing how the length of the questionnaire varied according to the number of health problems the athlete reported. Reproduction kindly authorized by B. Clarsen.



Bilingual native speakers translated both questionnaires mentioned above from English to French and German.

The third and last questionnaire used in this study is the "Profile of Mood State – Adolescents" (POMS-A, appendix 7), which was developed using the original POMS version by Terry (1971) in order to have an instrument validated within a population of adolescents. This version was later validated in an adult population (13). It consists of 24 adjectives representing the 6 base axes of mood (4 adjectives for each axis): anger, confusion, depression, fatigue, tension and vigour. Only 'vigour' is a positive mood. Thus the purpose is to capture the athlete's profile of mood state at a given moment.

The POMS-A was chosen primarily because most of our participants were adolescents, and also it is shorter than the original version (24 adjectives versus 65) and the adjectives used are easier to understand.
Every second Sunday, swimmers had to assess how each adjective corresponded to their mood state during the past week by choosing beetwen 0 (not at all) and 4 (extremely).

The French (11) and German (12) validated translations were used for the adjectives, which are used in both the POMS-A and in the original POMS version. The remaining adjectives were translated using language dictionaries and examined by bilingual native speakers.

The English, French and German versions of all questionnaires are to be seen in appendix 7.

Training log

Our training log consists of monitoring the 6 following parameters: rating of perceived exertion (RPE) and of the perceived satisfaction about the accomplished training, sport type, distance in meters, intensity according to the terminology of Swiss Swimming (appendix 8) and duration in minutes.

The session-RPE method is a validated tool used to measure the internal training load among a swimming population (16). We slightly modified the terminology of the modified Borg CR-10, in order to fix the moderate level at 4 (instead 3) and thus making the scale more symmetrical, and also to make it uniform with the terminology of our *satisfaction scale* and thus limiting possible confusion of the swimmers.

We developed a *satisfaction scale* in order to monitor the gratification provided by the training to the swimmer. Indeed, we suppose that the level of satisfaction could be a reliable marker of a lack of recovery and thus a tool, which could be used to prevent the overtraining syndrome.

Table 1 Modified Borg CR-10 and satisfaction scale

Rating of perceived exertion		Satisfaction scale	
1	Very very light	**1**	Very very low
2	Very light	**2**	Very low
3	Fairly light	**3**	Fairly low
4	Moderate	**4**	Moderate
5	Somewhat hard	**5**	Somewhat high
6	Hard	**6**	High
7	Very Hard	**7**	Very high
8	Very very hard	**8**	Very very high
9	Extremely hard	**9**	Extremely high
10	Maximal	**10**	Maximal

From the RPE and the duration of the training session, FITSTATS Performance automatically calculated the training load, the training monotony and the training strain using the following formulas:

Training load = RPE * duration (min)

Monotony = mean weekly training load / standard deviation of the training load

Training strain = training load * monotony

Competition results and time trials in training

Performances during competition have been compiled with the aid of the web site www.swimranking.net, in which the results of all swimming competitions worldwide are recorded. Swimmers were also asked to enter time trials swum during training on the web platform.

Table 2 Recorded data

Frequency	Data type	Reminders
Daily After every training session	<u>Training log :</u> 1) Rating of perceived exertion (RPE) using the modified Borg CR-10 RPE scale 2) Rating of the perceived satisfaction about the accomplished training 3) Sport type 4) Distance (meters, if swimming) 5) Intensity according to the Swiss Swimming Training terminology 6) Duration (minutes)	If no training was entered on the previous day, the webplatform sent automatically a reminder email on the following day.
Twice a week Every Tuesday and Friday	The Self-Assessment Questionnaire of Recovery Feeling	An email was sent on the day of completion and if needed, reminders were sent the day after (maximum 2 reminders).
Weekly Every Sunday	The Oslo Sports Trauma Research Center questionnaire on health problems	An email was sent on the day of completion and if needed, reminders were sent the day after (maximum 2 reminders).
Fortnighly Every second Sunday	The POMS-A	An email was sent on the day of completion and if needed, reminders were sent the day after (maximum 2 reminders).
Undefined frequency	Time-trials at training	None

Feedback

At the end of the study, the swimmers were asked to fill out a feedback form about their experience with the web platform FITSTATS and the training monitoring process in general. The swimmers were asked to answer the 4 questions listed in Table 3.

Table 3 Feedback questionnaire

1) Are you satisfied with your experience with the web platform "FITSTATS Performance"?
2) Were you able to perform all the requested tasks? If not, where did you encounter problems?
3) What could we do to improve the web platform?
4) Do you consider, that it is useful to keep a training log and perform daily monitoring of your performance and recovery level? If so, how does it help you ?

Compliance

Satisfactory compliance was pre-determined as >80% of response rate in every questionnaire.
Regarding the training log, satisfactory compliance was fixed at >75% of recorded training. We explain this difference by the following: the attendee lists, which were used as reference documents in order to calculate the percentage of recorded training, are unsure reference sources comparing to the other reference sources used in this study. It is the reason, why the threshold is lower for the training log.

Analysis

For the purpose of the master's thesis, we decided to analyse the results of "The Oslo Sports Trauma Research Center questionnaire on health problems" and their correlation with the recorded training loads. The remaining data will be analysed in detail at a later stage with the aim of publication.
"The Oslo Sports Trauma Research Center questionnaire on health problems" was analysed using descriptive statistical calculations, and the potential relationships with training load were established using Pearson's correlation coefficient. In contrast to the original paper regarding this questionnaire (8), it was not possible to classify injury into overuse and acute injury, because we did not perform clinical interviews during the study as the original authors (Carslen et al, 2013) did.

Swimmer's characteristics

Age at the start of the study, total mean training load, weekly mean training load, total mean distance and weekly mean distance were collected.
In order to give an estimate of the performance level of the participants, the best score at the start of the study in terms of FINA point 2013 was also recorded.
"The FINA Points Table allows comparisons of results among different events. The FINA Points Table assigns point values to swimming performances, more points for world class performances typically 1000 or more and fewer points for slower performances. The base times are defined every year, based on the latest World Record that was approved by FINA. For short course the base times are defined with the cut-off date of August 31st. For long course the base times are defined at the end of the year (December 31st)" (53).

Response rate

The response rate was calculated by dividing the obtained data by the expected data for all the questionnaires and by dividing the obtained training sessions by the training sessions recorded in the attendee list of the trainers.

Reported problems

The total numbers of health problem, injury and illness and their respectively parts of total amount were calculated.

Reported problems according to training-load periods

With references to Foster's work (33), four training-load periods were distinguished from weekly training load and competition dates as explained in Table 4 hereinbelow. The total number of health problem as well as the weekly health problem rate were calculated for each training-load period.

Table 4 Definition of training-load periods

Training-load period	Condition 1	Condition 2
Intensive training-load period	≥ 60% of the maximal individual training load	none
Moderate training-load period	< 60% of the maximal individual training load	Taper periods excepted
Winter taper period	1-3 weeks prior to the Short Course Swiss National Championships	If < 60% of the maximal individual training load
Spring taper period	1-3 weeks prior to the Long Course Swiss National Championships	If < 60% of the maximal individual training load

Prevalence of health problems

The percentages of swimmers experienced at least once a health problem, an injury or an illness were calculated, as well as weekly average prevalence of health problem and of substantial health problem (see below for definition).

Prevalence of specific pathologies

The prevalence of a pathology X was calculated by dividing the number of swimmer affected by this pathology during the whole study by the total number of swimmer taking part in the analysis.

Frequency of specific pathologies

The frequency of a pathology X was calculated by dividing the total number of person-weeks, in which this pathology appears, by the total number of person-weeks in which pathologies come out.

Mean number of episode per year

The mean number of episode per year was calculated by dividing the number of episode during the study by the total number of swimmers, who had a response rate over > 80% for "The OSTRC questionnaire on health problems". The result was then multiplied by 2 in order to have it per year.

Concerning the illnesses, a range was calculated, which corresponds to the range between the mean number of episode per year for pure URTI (for example) and the mean number of episode per year for pure URTI and mixed symptomatology, which contained URTI as well.

Severity of specific pathologies

The severity was estimated by calculating the Severity Score according to Clarsen et al. (2012): "the responses to each of the four keys questions of "the OSTRC questionnaire on health problems" are allocated a numerical value from 0 to 25, and these are summed in order to calculate a severity score from 0 to 100 for each health problem. The response values were allocated such that 0 represents no problems and 25 represents the maximum level for each question. The values for intermediate responses were chosen in order to maintain as even a distribution from 0 to 25 as possible while still using whole numbers. Therefore, questions 1 and 4 are scored 0-8-17-25, and questions 2 and 3 are scored 0-6-13-19-25." (8)

Time-loss due to specific pathologies

Additionally, the severity was estimated by the time loss, which was a consequence of a health problem.

Substantial health problems

Clarsen et al. (2013) define substantial health problems as "those leading to moderate or severe reductions in training volume, or moderate or severe reductions in sports performance, or complete inability to participate in sport (i.e. problems where athletes selected option 3, 4 or 5 in either Questions 2 or 3 of "The OSTRC questionnaire on health problems").

Correlation with the training load

Figure 3 illustrates all the Pearson correlation coefficients, which were calculated.
Pearson correlations between "total weekly training load" and all health parameters illustrated in Figure 3 were calculated for the group of 27 swimmers and for each swimmer individually as well.
On the contrary, correlations between "mean weekly training load" and these health parameters were calculated only calculated for the group of 27 swimmers and not for each swimmer individually.

Feedback analysis

The percentage of swimmers taking part in the feedback was recorded and the questions 1 and 4 were analysed according to a binary code type yes or no. Additionnaly, we analysed qualitatively the last part of question 4, i.e. "if you consider, that it is usefull to keep a training log and perform daily monitoring of your performance and recovery level, how does it help you? "
For the purpose of this master's thesis, the questions 2 and 3 were not analysed.

Figure 3 Pearson correlations between training load and all the heatlh parameters used in the study

CHAPTER THREE

Results

Swimmers' characteristics

The initial cohort of 38 swimmers included 2 male Swiss record holders, 5 male national team members and 9 female regional team members. The youngest swimmers were 13 years old whereas the oldest participant was 26 at the start of the study (mean ± SD 17.5 ± 2.8 years).

Table 5 shows the characteristics of the 31 swimmers, who have a response rate >80% for "The OSTRC questionnaire on health problems". The training-related data outlined in the table concern the swimmers who also had a response rate >75% for the training logs.

Table 5 Swimmer's characteristics

Characteristics	Value	Standard deviation
Number of swimmers	31	
Age (year)	17.0	± 2.7
FINA points 2013	576.0	± 128.0
Total mean training load	75472.2	± 18938.8
Weekly mean training load	2979.4	±712.8
Total mean distance (m)	514947.0	± 156487.9
Weekly mean distance (m)	20370.4	± 5958.5

Response rate

The data concerning all 35 swimmers who completed the study are shown in Table 6.

31 swimmers have a response rate > 80% for "The OSTRC questionnaire on health problems", 27 of whom additionally have a training log response rate >75%.

Percentages concerning the training log are in brackets, because the reference source used (i.e. the attendance list done by the trainers) carries a certain degree of uncertainty compared to the other reference documents. Red indicates percentages below the response rate threshold.

Although swimmer B9 had a response rate for the training log of 74,8% (indicated hereinbelow in yellow), we decided to include him in the analysis as the reference source could not be validate for certain and the other parameters entered by this swimmer pointed to an excellent compliance.

Three swimmers dropped out during the study, due to time restrictions for participation, changing swimming clubs and one retired from swimming. They recorded very few data, so they will not be analyzed in this paper.

Table 6 Response rate to questionnaires and training logs

Swimmer	Recovery	OSLO	POMS-A	Training log
A1	98.1%	100%	100%	(95.8%)
A2	100%	100%	100%	(99.5%)
B3	100%	100%	100%	(79.9%)
B4	100%	100%	100%	(75.7%)
B5	100%	100%	100%	(92.9%)
B6	100%	100%	100%	(82.3%)
B7	100%	100%	100%	(66.7%)
B8	100%	100%	100%	(89.7%)
B9	96.2%	100%	100%	(74.8%)
B18	86.5%	92.3%	76.9%	(70.7%)
B29	100%	100%	100%	(78.6%)
C10	100%	100%	100%	(96.2%)
C11	98.1%	100%	100%	(97.8%)
C12	100%	100%	100%	(96.7%)
C13	100%	100%	100%	(98.8%)
C14	96.2%	100%	100%	(98.5%)
C16	98.1%	100%	100%	(96.7%)
D19	73.1%	76.9%	76.9%	(77.5%)
D21	96.2%	100%	100%	(90.8%)
D22	100%	100%	100%	(97.3%)
D30	92.3%	100%	92.3%	(72.1%)
D35	100%	100%	100%	(94.1%)
E23	98.1%	100%	100%	(96.9%)
E24	100%	100%	100%	(89.4%)
E26	100%	100%	100%	(96.0%)
E27	100%	100%	100%	(96.8%)
E28	100%	100%	100%	(97.5%)
E31	98.1%	100%	92.3%	(95.1%)
E32	94.2%	96.2%	92.3%	(87.2%)
E33	100%	96.2%	92.3%	(88.8%)
F20	44.2%	57.7%	53.8%	(35.7%)
F25	98.1%	92.3%	92.3%	(80.4%)
F36	75.0%	84.6%	84.6%	(57.3%)
F37	42.3%	53.8%	53.8%	(6.3%)
F38	50.0%	61.5%	61.5%	(21.0%)

Reported problems

During the 26 weeks of the trial, a total of 241 health problems were reported, including 173 injuries and 68 illnesses, which represent respectively 71.8% and 28.2% of the total amount of reported health problems.

Reported problems according to training-load periods

For this analysis, only the data of the 17 swimmers, who competed in both Short Course Swiss National Championships and Long Course Swiss National Championships and who had a response rate ≥ 80% for "The OSTRC questionnaire on health problems" and ≥ 75% for the training log, were taken into account.

As indicated in Table 7 hereinbelow, weekly rate of health problem and weekly rate of injury are the highest during the moderate-training load period, while weekly rate of illness is the highest in both moderate-training load and winter taper period. The intensive training-load period and the spring taper period are comparable in terms of injury, illness and health problems.

The winter taper period is similar to the intensive training-load period in terms of injury, but during the winter taper period illnesses are more frequent than during the intensive training period.

Finally, the both taper period are comparable, excepted for the illness rate, which is two times higher during the winter taper period.

Table 7 Reported health problems according to training-load periods

Training period	Type of health problem	Number of health problem	Number of week	Weeky health problem rate
Intensive training-load period	Injury	16	135	0.12
Intensive training-load period	Illness	7	135	0.05
Intensive training-load period	Health problem	23	135	0.17
Moderate training-load period	Injury	44	219	0.20
Moderate training-load period	Illness	20	219	0.09
Moderate training-load period	Health problem	64	219	0.29
Winter taper period	Injury	5	41	0.12
Winter taper period	Illness	4	41	0.10
Winter taper period	Health problem	9	41	0.22
Spring taper period	Injury	6	47	0.13
Spring taper period	Illness	2	47	0.04
Spring taper period	Health problem	8	47	0.17

Prevalence of health problems

During the whole study, 90.3% of the swimmers experienced at least one health problem, while 67.7% experienced at least one injury, and 77.4% an illness.

The weekly average prevalence of health problems was 27.0% with 13.2% of the swimmers reporting substantial health problems each week.

Injury

According to the results shown in Table 8, the shoulder (including clavicle) is the most frequently injured body part (n = 81, 46.8%), the one which concerns the most swimmers (n=14, 45.2%) and which has the worst impact in terms of time-loss (n=44, 29.5%) as well as the highest severity score (n= 3368, 48.4%).

It is interesting to note, that the second most injured body part in terms of severity is the elbow, which occured in only 3 swimmers, all of whom are regular backstroke swimmers.
The mean number of shoulder injury per year is 5.2.

Table 8 Injury prevalence, ranked from highest to lowest severity score

Injury	Number of swimmers	Frequency (person-weeks)	Time-loss (days)	Severity Score
Shoulder (including clavicle)	14	81	44	3368
Elbow	3	31	39	1491
Thigh	3	22	10	664
Neck	4	5	5	319
Hand/fingers	3	5	21	278
Knee	5	11	3	265
Lumbar spine	3	3	8	128
Thoracic spine	2	3	1	107
Wrist	1	4	3	92
Chest/ribs	2	2	7	89
Other	2	2	6	51
Upper arm	2	2	1	44
Pelvis and buttock	1	1	1	37
Forearm	1	1	0	22
TOTAL	46	173	149	6955

Illness

The most common illness is the upper respiratory tract infection or URTI (n= 28, 41.2%). It concerns the majority of swimmers (n= 26, 83.9%) and has the most serious impact in terms of severity score (n= 882, 33.4%). Abdominal symptoms are the second most common illness as shown in Table 9, followed by a combination of both.
The mean numbers of episode per year is between 1.8 and 2.2 for the URTI and between 1.0 and 1.4 for abdominal symptoms.

Table 9 Illness prevalence, ranked from highest to lowest severity score

Illness	Number of swimmers	Frequency (person-weeks)	Time-loss (days)	Severity Score
URTI	26	28	17	882
Abdominal symptoms	14	15	22	632
URTI + Abdominal symptoms	4	5	14	308
URTI + Ear symptoms	4	4	8	148
Fatigue/malaise	3	4	2	133
Ear symptoms	3	3	6	117
Headache	2	2	5	109
Conjunctivitis	1	1	3	60
Nausea	1	1	3	60
Rash/itchiness	1	1	1	56
URTI + Abdominal symptoms + Ear symptoms	1	1	0	39
Depression/sadness	1	1	2	37
Headache + Abdominal symptoms	1	1	1	37
Arrhythmia	1	1	0	22
TOTAL	63	68	84	2640

Correlation with training load

For the 27 swimmers who had a response rate >80% for the OSLO and >75% for the training log, Pearson correlation coefficients were calculated.
All the group correlations were non-significant as shown in Tables 10 to 13. Significant individual correlations were only found for the swimmer D21, namely between weekly total/mean training load and all the illness and health problems parameters as shown in Table 14. Blank box means, that it is not possible to calculate a correlation because the injury matrix is only composed of 0.

Table 10 Pearson correlations between the total number of health problems and the training load

	Weekly total training load	Weekly mean training load
Weekly total number of injuries	0.13	0.16
Weekly total number of illnesses	-0.04	-0.07
Weekly total number of health problems	0.09	0.10

Table 11 Pearson correlations between the total number of substantial health problems and the training load

	Weekly total training load	Weekly mean training load
Weekly total number of substantial injuries	0.26	0.25
Weekly total number of substantial illnesses	0.02	-0.03
Weekly total number of substantial health problems	0.25	0.22

Table 12 Pearson correlations between the missed days because of health problem and the training load

	Weekly total training load	Weekly mean training load
Weekly missed days because of injuries	0.15	0.16
Weekly missed days because of illnesses	-0.16	-0.21
Weekly missed days because of health problems	0.00	-0.02

Table 13 Pearson correlations between the severity score and training load

	Weekly total training load	Weekly mean training load
Weekly severity score of injuries	0.40	0.42
Weekly severity score of illnesses	-0.04	-0.08
Weekly severity score of health problems	0.34	0.34

Table 14 Pearson correlations for the swimmer D21

	Weekly total training load
Weekly total number of injuries	
Weekly total number of illnesses	-0.52
Weekly total number of health problems	-0.52
Weekly total number of substantial injuries	
Weekly total number of substantial illnesses	-0.58
Weekly total number of substantial health problems	-0.58
Weekly missed days because of injuries	
Weekly missed days because of illnesses	-0.53
Weekly missed days because of health problems	-0.53
Weekly severity score of injuries	
Weekly severity score of illnesses	-0.56
Weekly severity score of health problems	-0.56

Feedback

71.4% of the swimmers took part in the feedback survey (n=25). 100% of respondents declared that they were satisfied with their monitoring experience with the web platform "FITSTATS Performance". 92.0% reported that it was useful to keep a training log and perform a daily monitoring of their performance and their recovery level.

Moreover, many swimmers highlighted that taking part in this study was beneficial because it helped them become aware about what they were doing during training, their feelings and satisfaction regarding the accomplished training, about the link between training, recovery and performance, and it helped them think about the above-mentioned topics.

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CHAPTER FOUR

Discussion

This study was a pilot prospective attempt with the purpose of finding relevant correlations between training, health, recovery parameters and swimming performance, in order to detect a state of fatigue and thus assist in preventing an overtraining syndrome or other health–related issues.
The monitoring of training and recovery are nowadays of great interest. Firstly, because athletes, coaches, sport scientists and sport physicians have realized the value data can bring to training itself and to the athlete's health (36, 37). Secondly, because of the enormous technological progress and simplification enabling the easy use of such a monitoring system.
In a general manner, good competitive athletes, who are not elite athletes and thereby not integrated in a performance center, do not usually benefit from sport sciences support and have limited access to sophisticated data monitoring systems. Additionally, collected data is frequently not analysed or utilised appropriately (52). For these reasons, a monitoring system and its analysis processes have to remain simple so it can be used not only by elite athletes but also by lower-level competitive athletes.

As described above, we analysed for the purpose of this master's thesis, the results of "The Oslo Sports Trauma Research Center questionnaire on health problems" and their correlation with the recorded training load. It is planned to analyse the remaining data at a later stage in order to produce a publication.

The main finding of the present study was that at any given time during the macrocycle 27.0% of the swimmers reported health problems, which included 13.2% of substantial health problems. Clarsen et al. (2013) define substantial health problems as "those leading to moderate or severe reductions in training volume, or moderate or severe reductions in sports performance, or complete inability to participate in sport (i.e. problems where athletes selected option 3, 4 or 5 in either Questions 2 or 3 of "The OSTRC questionnaire on health problems").
This is quite comparable with the results of Clarsen et al. (8), who reported in their study on Olympic and Paralympic athletes on the road to the 2012 Olympic Games, an incidence of 36% of health problems and 15% of substantial health problems. This is despite the level difference in the athletes' populations between the studies.

Regarding the injury, the most frequent checked item was "the shoulder (including clavicle)" one. Considering the papers of Chase et al. (14) and Wanivenhaus et al. (15), it is highly probable, that the majority of the pathologies included in this item are shoulder's one and not clavicula's one, which are very atypical for swimmer. Thus it would be discussed hereinbelow only about shoulder's injuries.
So shoulder injury is the most frequent one, the one which concerned most swimmers and which had the largest impact in terms of time-loss and severity score. This confirmed the results of Chase et al. (14) and Wanivenhaus et al. (15), whose literature

search reveal that shoulder injury represent 40-91% of all injuries amoung elite swimmer (15).
In order to understand the pathophysiology of shoulder injury in swimming, it is necessary to know both swimming and biomechanics of the shoulder.
In swimming, in contrast to many other sports, it is mainly the upper limbs, and not lower ones, that propel the body forward. Additionnaly, swimmers repeat a lot the same movements. For example, the weekly mean distance in this study was about 20'000 meters. On the notion that, a competitive swimmer realizes about 14 shoulder revolutions for 25 meters, swimmers taking part in this study realize about 11'200 shoulder revolutions each week during 6 months.
The shoulder is a joint which enables movements in all directions but his stability is precarious and requires integrity of both dynamics and statics stabilizers. Dynamics stabilzers refer to muscle of the shoulder, scapula and upper back, and static stabilizers to glenoid labrum and capsular ligaments.
According to the literature search of Wanivenhaus et al. (15), it is nowadays established, that there are 3 main factors explaining shoulder injury in swimmer: 1) stroke biomechanics and/or 2) overuse and fatigue of muscles of the shoulder, scapula and upper back and/or 3) glenohumeral laxity with subsequent shoulder instability.
First, swimming biomechanics itself could cause subacromial impingement, e.g. during the above-water portion of the stroke (also called recovery phase), the forward flexion and internal rotation of the shoulder lead the joint to a subacromial impingement. This phenomenon could be aggraved if muscle fatigue appears.
Secondly, swimming does not use all upper limb muscles equally. Indeed adduction and internal rotation, executed by pectoralis major and latissimus dorsi respectively are overused in comparison to abduction and external rotation. This point leads to muscle imbalance, and thus shoulder instability.
Lastly, according to Pink et al. (39), only 20% of swimmers have a generalized ligamentous laxity, which means that genetic alone does not explain the common shoulder laxity in swimmer. In that way, Rupp et al. hypothesized that shoulder laxity develops over time due continual overuse. Up to a point, high laxity of the shoulder enables a body position reducing drag and a greater stroke length, which is advantageous. But beyond a certain point of laxity, the joint become instable and active stabilizers have to work more, which leads to muscle fatigue.
To date, altered swimming movements due to muscle fatigue and laxity of the shoulder may lead to functional shoulder impingement, which is to distinguished from the typical shoulder impingement found in a normal population. This last one is indeed caused by structural subacromial changes.

With regards to illness, our results reflect the work of Clarsen et al. (8) in that the most frequent illnesses concerned the upper respiratory tract followed by problems of the digestive system. Our study highlights that the Upper Respiratory Tract Infection concerns most swimmers and causes the worst impact in terms of severity score, but not in terms of time loss, which was due to illness of the digestive system.
Because our results match the ones of Clarsen et al. (8), which are obtained amoung athletes of 17 different Olympic and Paralympic sports, these illnesses are not exclusive of swimmers and thereby may not be explained by typical swimming condition such as the water environment. Moreover, the mean number of episode per year for URTI is

similar to the one found in the general adult population (i.e. 2 to 4 episode per year) (41, 42, 43).
Thus our participants are not more ill than other athletes or than the general adult population. This means, that they have not experienced time-limited training-induced immunodeficiency, which usually followed high intensity exercice (also called "open window") (1, 38) or if they experienced it, it did not lead to clinical consequences.
The reason explaining, that both respiratory and digestive systems are more likely than other ones to be affected in athletes as well as in the general population lies in the fact, that both respiratory and digestive tracts are directly exposed to the environment and thus more vulnerable to pathogen agents like viruses.

The distribution of the health problems among the four training-load periods highlights, that the most critical period regarding injury and illness is the moderate training-load period and not the intensive training-load period.
The following hypothesis may explain this: as swimmers passed more time in the moderate training-load period than in the intensive one, it is more likely that overuse injuries, which are the most frequent injuries in elite athletes (8), appear during this period rather than during the intensive one.
A second hypothesis may be, that because sessions of the moderate training-load period as stamped as not intensive ones, the recovery may be a little bit neglect from the swimmer's side as well as from the coach's side. From the swimmer's side means, that he could be, e.g. less carefull of sleep quantity and quality or of nutrional aspects. From the coach side means, that the coach could include less recovery sessions or make recovery sessions harder than usuall. This may illustrates the citation of Dr Philip Skiba, Director of Sports Medicine at Lutheran General Hospital (Park Ridge, Illinois, @DrPhilipSkiba on Twitter): "The best way to overtrain someone is not to make their hard workouts harder, but their easy workouts harder".
Regarding the illness, the elevated weekly rate obtained for the winter taper period matches, on the one hand, the results of Hellard et al. (38), who find as well that there are more illnesses in winter. But on the other hand, they found, that illnesses are concentrate "in winter and during the heaviest training periods", while our study highlights, that the most critical period regarding illness is a taper one! This is empirically well known by swimmers and swimming coaches.

All correlations calculated above, as shown in Figure 3, were non-significant (with the exception of one swimmer). This suggests that health problems are NOT related to training load in our sample of athletes.
In the literature, there are some discrepancies regarding the relationship between illness and training load. Some autors found a relationship (38, 43, 44, 45), while other ones did not find one (46, 47, 48). Hellard et al. (2014) suggest, that the explantion may lie in methodological limitations such as different athletic level, small sample size or observation period that differ in length.
Contrasting to this, the relationship between injury and training load is nowadays well established in field and collision sports such as rubgy or Australian football (19, 49, 50, 51). However and as far as we know, there is no publication studying this issue among swimmers.

Considering that, the URTI are not more frequent among our swimmers population than in the general one, it is not suprising that illness are not correlated with the training load. A potential explanation for this may be that the majority of our population was too young and thus did not train "enough" in term of intensity and/or volume in order to develop illness linked to the time-limited training-induced immunodeficiency.
Regarding the injuries and as mentioned above, there is to our knowledge no evidence of the relationship between training load and injury amoung swimmers. However, it seems to be logical, that above a certain threshold of training load, injuries have to pop-up (particularly for overused injuries) as in other sports. Because of the particular environment of swimming, it may be possible, that this threshold is more elevated than in other sports. This point, coupled with the hypothesis that our swimmers may be not train enough, could explain why they did not reach this threshold.
Supplementary explanations may be that the injury and illness occurrence were due to other factors not analysed in this paper, like psychological factors associated with training and lifestyle stress, nutritional aspects or recovery factors.
To date, general limitations of the present study may be the small size of the sample and the disparate swimming level of the participants.

Additionally, our study highlights that most swimmers found useful keeping a training log, performing daily monitoring of their performances and of their recovery using an online tool. This confirms the recommendation of Halson (20), who advises working with an easy to use online tool in order to monitor training and recovery.
But the most important may be that, such a process develops the perception of young athletes regarding their body including fatigue and recovery sensations and it highlights the necessity to recover well in order to increase their performances.

CHAPTER FIVE

Conclusion

This study was a pilot prospective attempt to develop a reliable system to monitor training load, recovery, health and performance in swimming. This process may assist in preventing the occurrence of an overtraining syndrome and of overuse injuries and illnesses during swimming training phases.

Our results confirm that the shoulder is the most commonly injured area of the body and that the respiratory and digestive tracts are the most common systems involved in illnesses in a competitive swimming population.

The critical training period regarding injury and illness is the moderate training-load period and not the intensive training-load period. Concerning the illnesses, the winter taper period is as critic as the moderate training–load period. This last point emphasizes, that coaches and swimmers have to be particularly aware of the recovery process during the winter taper period in order to reach the major competition at the top of their form.

We could not show that health problems, injuries and illnesses are correlated to training load but further explorations into other factors such as psychological stress are required.