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Vaccination status of elite athletes in the German Armed Forces: a retrospective descriptive overview

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Purpose: Vaccination of athletes is an effective preventive intervention to maintain athletic performance. Data reporting the vaccination status of elite athletes are limited. Aim of this study was to provide an overview about the vaccination status in elite athletes who were affiliated to the German Armed Forces.
Materials and Methods: Six hundred seventy athletes were included in this retrospective cross-sectional study. Statistical analysis was performed using McNemar's test, φ coefficient and logistic regression.
Results: The 0.3% of all included athletes had a complete vaccination status as recommended by the German Standing Commission on Vaccination when they started their career. Regarding the different kinds of vaccination, there was a range from 3.0% (influenza) to 69.6% (mumps, measles, rubella). Although a valid vaccination status is mandatory for soldiers, only 6.3% of the athletes had a valid one at the time of data collection. During the observation period, only few athletes worsened their vaccination status. Specific differences could be seen for different kinds of sports. Swimmers and sleigh drivers were almost completely below average. The vaccination status among Taekwondo Fighters and Fencers were almost entirely above average. Worse vaccination status was found for vaccinations that required more frequent repetition. The vaccination status was comparable for vaccinations that are available as combination vaccines.
Conclusion: Although a complete vaccination status was mandatory, there were vaccination gaps. It seems necessary to be more stringent in the prevention of vaccination gaps. Athletes, physicians, and sports associations should cooperate to find an effective way to get optimum prevention.

Keywords: Vaccination; Elite athletes; Sports; Prevention; Immunization

INTRODUCTION

Vaccinations have been used for many decades as an effective specific prophylaxis to protect against infectious diseases [1].

Even mild infections can affect athletic performance and hamper participation in competitions [2]. Frequent travel, the practice of contact sports and living in residential accommodation increased the exposure, what led to a comparatively higher risk of infection among elite athletes compared to the general population [3-6]. Additionally, epidemic outbreaks during major sporting events have been described frequently in the past, e.g. influenza outbreaks during the Winter Olympics in Salt Lake City 2002 or measles outbreaks in the USA [7-9]. Moreover the phenomenon of the "open window" was described for athletes, the immune system is weakened by sports and the body is more susceptible to infectious diseases [10-12]. Although the "open window" phenomenon represents a weakening of the immune system, it is not an obstacle to an adequate immunological response to vaccination in athletes. A normal to increased immune response was observed [13].

According to the German Standing Commission on Vaccination (STIKO), comprehensive vaccination protection should be guaranteed for life [1]. Athletes should be vaccinated as early as possible, missed vaccinations should be applied as soon as possible and regular booster vaccinations should be carried out [1]. If no single vaccines are available, combination vaccines should be used as a substitute. The benefit of vaccination outweighs a possible risk of overvaccination [1,14].

In general, the STIKO recommends various basic immunizations and booster vaccinations at different ages [1]. Moreover, there are further possibilities for vaccination for occupational indication, individual indication or as travel vaccination [1]. Athletes have to be individually checked for other influencing factors such as previous operations or chronic diseases [15]. Prior to travel, destinations should be investigated for possible outbreaks of infectious diseases or endemics with regard to the further need of vaccination [16].

The German Armed Forces are part of the German system to support elite athletes. Athletes serve as regular soldiers for the time they are active athletes. To stay in training and competition is their duty. The implementation of protective vaccination within the German Armed Forces was based on various vaccination schedules and is also bindingly valid for elite athletes. If the vaccination status is incomplete no coercion is executed to get vaccinated but disciplinary consequences are possible.

The vaccination schemes of the German Armed Forces corresponded to the recommendations of the STIKO [17]. Indication-based vaccinations or vaccinations for occupational indication were carried out in addition to the standard vaccinations.

Overall, the data on the vaccination status of both military personnel and elite athletes is limited. Athletes in Germany should have a vaccination status according to the current STIKO's recommendation. In addition to recommended vaccinations, there may be individual indications for further vaccination depending on the type of sport [18]. In a survey of 270 amateur basketball players, the vaccination status for tetanus was only 73% [19]. There were also significant vaccination gaps worldwide among military personnel [20,21]. Therefore, significant vaccination gaps are also to be assumed among elite athletes in the German Armed Forces, but no data are currently available. Comparative data regarding different sports is missing. In the light of this, for the first time, this study provides an overview about the vaccination status of elite athletes of different sports via the German sports supporting system. Differences or correlations linked to the performed sports will be pointed out.

MATERIALS AND METHODS

Patients

This cross-sectional retrospective study was conducted with elite athletes of the German Armed Forces. It was approved by the responsible local Ethics Committee (file reference: A 2020-0211).

Medical records of 913 athletes were evaluated, 670 athletes could be included in the process of data collection. **Table 1** shows the characteristics of the study population.

For a more meaningful analysis it was necessary to arrange the amount of data to groups based on the performed sport. Only the 10 largest groups by members were considered (n=354, 19 to 100 members per sport) due to the low number of athletes in other disciplines and regarding the resulting limitations of the used statistical procedures.

Data collection

Data were collected from the medical records and from the German vaccination record from January 2021 up to August 2022. Vaccination status was recorded at the time of entry into the German Armed Forces and at the time of data collection.

Table 1. Description of the total study population

Groups	Total (N=670)
Sex (female)	245 (36.6)
Sex (male)	425 (63.4)
Age (yr at time of entry)	20.6±2.9
Age (yr at time of data collection)	25.3±4.7
Observation time (mon)	40 (3–331)
Height (cm)	178±10
Weight (kg)	74.5±13.9
BMI (kg/m^2)	23.1 (16.9–38.9)

Values are presented as mean ± standard deviation or median (interquartile range) or number (%).
BMI, body mass index.

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A vaccination status according to STIKO's recommendation was considered a valid vaccination status. The following vaccinations have been considered: diphtheria, tick-borne encephalitis (TBE), hepatitis A, hepatitis B, influenza, measles, mumps, pertussis, poliomyelitis, rubella, and tetanus. Vaccinations against measles, mumps, and rubella (MMR) were recorded together, since only combination vaccines are available in Germany [1,22]. Only 317 athletes provided an International Certificate of Vaccination for inspection. Further information about vaccination could be obtained from the medical records. Documentation of performed vaccinations and titer determinations were included. Patients without any documentation were excluded.

Statistical evaluation

Pseudonymized data were entered into a spreadsheet in Excel for macOS, version 16.66.1 (Microsoft Corporation, Redmond, WA, USA). Statistical analyses were carried out using SPSS for macOS, version 29.0.0.0 (IBM Corporation, Armonk, New York, NY, USA).

To test for a statistically significant difference in the vaccination status of each subject between the beginning and end of the observation period, McNemar's test was used. The association between sex and vaccination status at both times was examined using the φ coefficient. Graphical testing for normal distribution using a histogram revealed no normal distribution for age. The association between age and vaccination status was investigated using logistic regression.

All results are exploratory, not confirmatory. The local significance level of all tests was set to α=0.05 without adjustment for multiple testing.

RESULTS

Description of the vaccination status

At the time of entry, only 2 athletes (0.3%) had a complete valid vaccination status for recommended vaccinations. At the time of data collection, 42 athletes (6.3%) had a complete valid vaccination status. Only one athlete (0.15%) had a complete valid vaccination status at both times. Regarding the different kinds of vaccination (**Fig. 1**), the vaccination status at the time of recruitment ranged from 3.0% (influenza) to 69.6% (MMR). By the time of data collection, vaccination status ranged between 18.1% (influenza) and 80.0% (MMR). An increase could be seen for all types of vaccinations. Vaccination rates for diphtheria, pertussis, poliomyelitis, and tetanus were similar, with slightly higher rates for diphtheria and tetanus. Hepatitis B had a higher level than hepatitis A, but the increase over the time was similar for both vaccinations. At both times influenza had the lowest and MMR the highest level. TBE vaccination was present at a low level.

Association of vaccination status and sex

Examination for sex specific differences in vaccination status for each vaccination revealed no relevant correlations at the time of recruitment and at the time of data collection (**Table 2**).

Association of vaccination status and age

At the time of recruitment, there was no statistically significant correlation for hepatitis A, hepatitis B, influenza, MMR, and TBE. There were significant correlations for diphtheria, pertussis, poliomyelitis, and tetanus, these vaccination status correlated negatively with increasing age at the time of entry (**Table 2**).

Table 2. Association of sex and age with vaccination status and sex at the time of entry in the German Armed Forces and at the time of data collection (N=670)

Variables	Sex		Age					
	Time of entry	Time of data collection	Time of entry			Time of data collection		
	φ coefficients	φ coefficients	OR	p-values	95% CI	OR	p-values	95% CI
Diphtheria	0.058	–0.011	0.884	<0.001	0.836–0.935	0.957	0.021	0.922–0.993
Hepatitis A	0.047	0.031	1.041	0.183	0.981–1.106	1.073	<0.001	1.037–1.111
Hepatitis B	0.039	0.034	0.962	0.206	0.905–1.022	0.992	0.645	0.960–1.025
Influenza	0.013	0.038	0.837	0.117	0.670–1.046	0.914	<0.001	0.871–0.960
MMR	0.038	–0.023	0.940	0.027	0.890–0.993	0.916	<0.001	0.881–0.952
Pertussis	0.043	–0.026	0.852	<0.001	0.803–0.904	0.940	<0.001	0.906–0.975
Poliomyelitis	0.060	–0.026	0.894	<0.001	0.845–0.945	0.974	0.162	0.939–1.011
TBE	0.025	0.039	0.939	0.154	0.862–1.024	0.973	0.166	0.937–1.011
Tetanus	0.066	–0.017	0.886	<0.001	0.838–0.937	0.963	0.052	0.928–1.000

OR, odds ratio; CI, confidence interval; MMR, mumps, measles, rubella; TBE, tick-borne encephalitis.

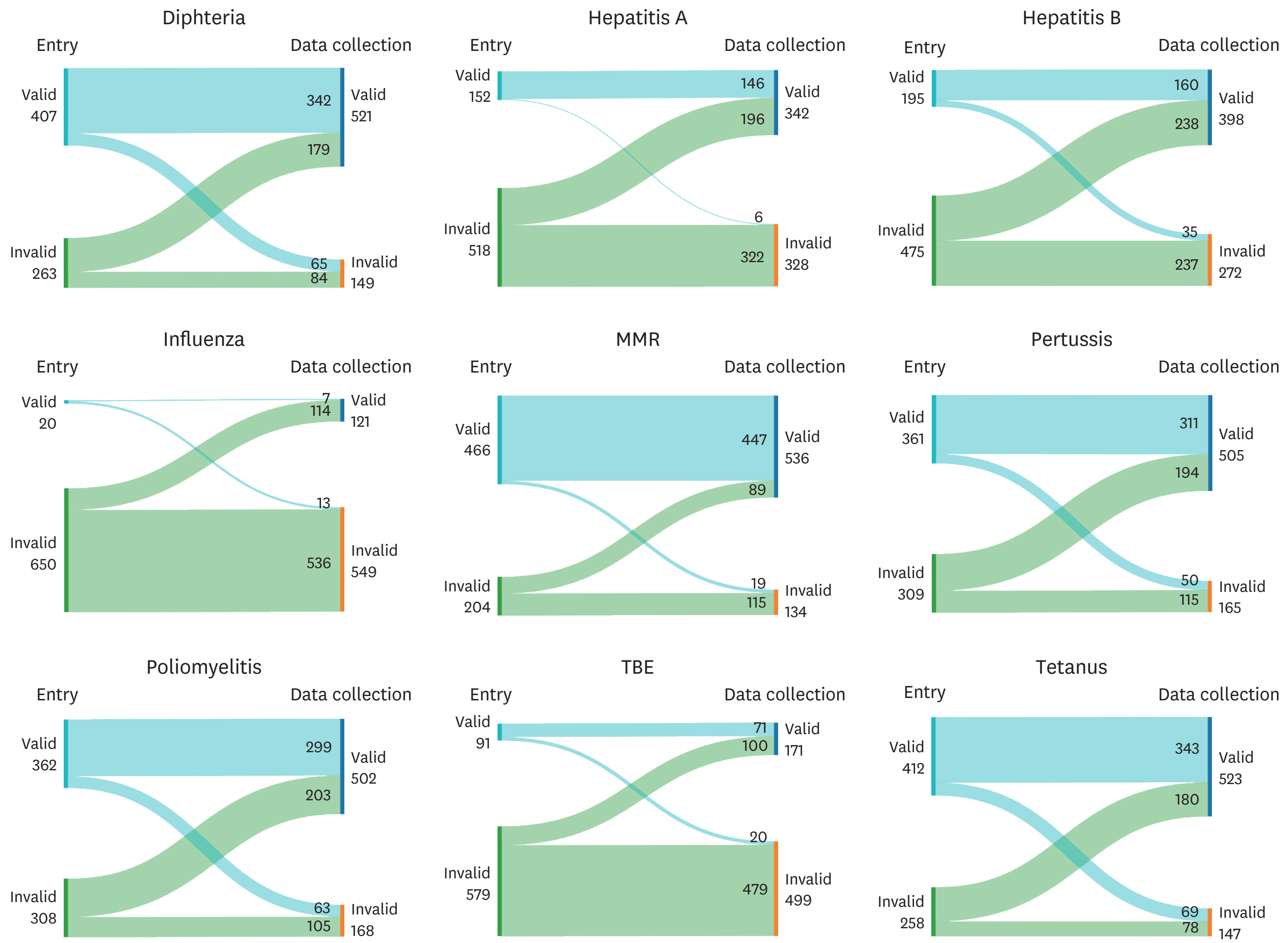

Fig. 1. Development of the vaccination rate from entry into the German Armed Forces to the time of data collection (N=670). The Sankey diagram shows the change in the vaccination status as directional arrows proportional to the quantity.
MMR, mumps, measles, rubella; TBE, tick-borne encephalitis.

Significant results at the time of data collection could be observed for hepatitis A, influenza, MMR, and pertussis. While there was a positive correlation between age and vaccination against hepatitis A at the time of data collection, influenza, MMR, and pertussis correlated negatively. No statistically significant correlations were found for diphtheria, hepatitis B, poliomyelitis, TBE and tetanus (**Table 2**).

Development of vaccination status

Fig. 1 demonstrates the change in vaccination status during observation period. Six percent of the athletes changed from an invalid to a valid vaccination status. A small number of athletes showed the transition from a valid to an invalid vaccination status. Most changes occurred for hepatitis B, the fewest for MMR. Concerning diphtheria, MMR, pertussis, poliomyelitis, and tetanus most athletes had valid vaccination status at both times. Regarding hepatitis A, hepatitis B, influenza, and TBE most athletes had an invalid vaccination status at both times. Influenza was mostly represented in the category invalid vaccination status, only 7 athletes had valid vaccination status at both times. TBE vaccination status showed similar results. Changes for diphtheria and tetanus were similar, along with pertussis and poliomyelitis.

Vaccination status and relation to the performed sports

Ten different sports with the largest numbers of athletes were compared regarding their vaccination status. Of these, 2 athletes had a complete valid vaccination status at the time of entry and 21 athletes had a complete valid vaccination status at the time of data collection.

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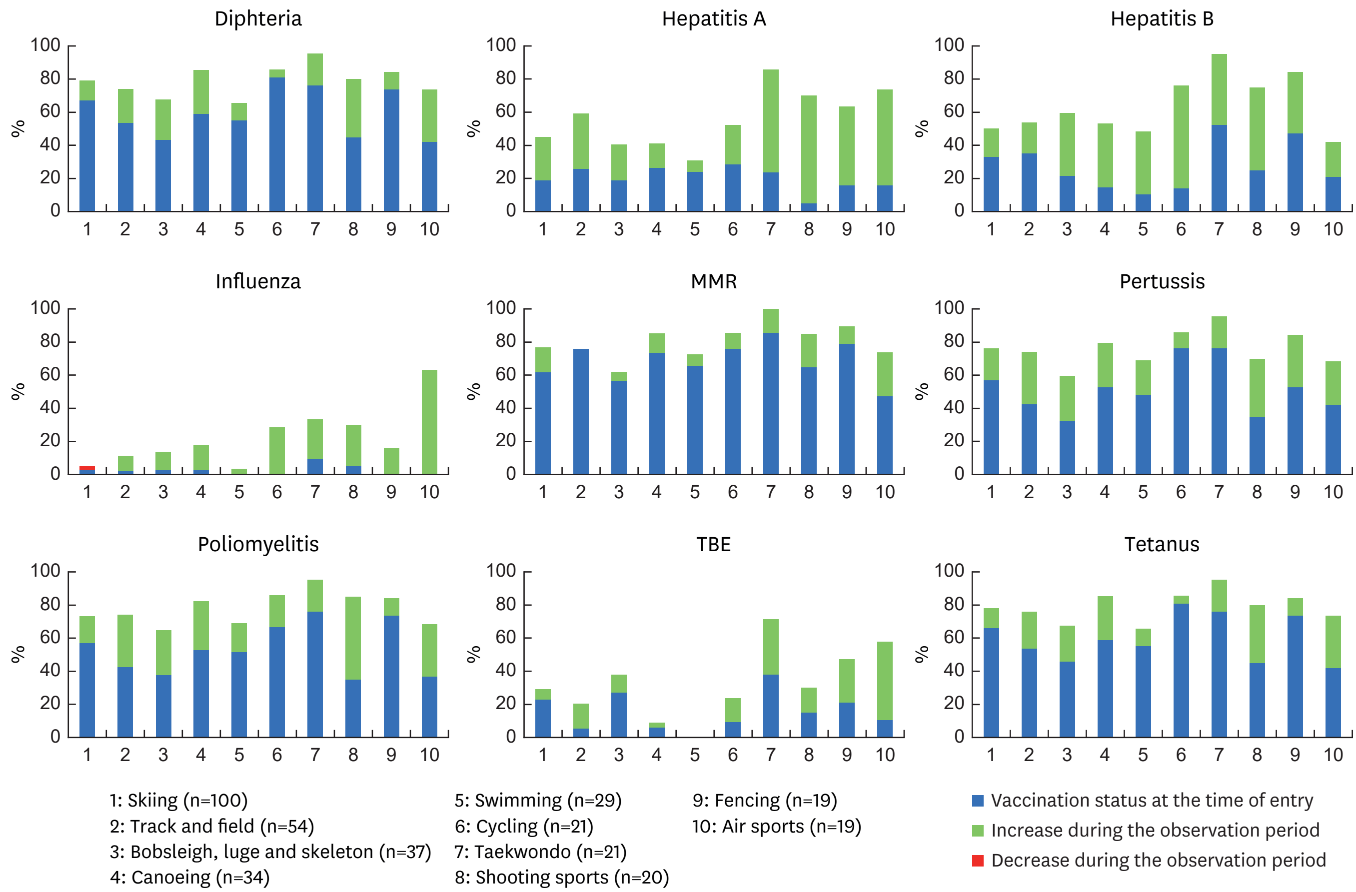

Fig. 2. Vaccination status and increases in the 10 associations with the highest number of members (n=354).
MMR, mumps, measles, rubella; TBE, tick-borne encephalitis.

Overall, there was a very heterogeneous distribution of above- and below-average vaccination status in the different sports. Frequently, the vaccination status was particularly high or particularly low for all vaccinations in a specific sport. This could be observed at the time of entry and at the time of data collection. Vaccination status from German taekwondo fighters and fencers were almost exclusively above average. In contrast, the vaccination status in swimmers and bobsleigh drivers, were almost exclusively below average. At the time of recruitment, no athlete in swimming, cycling, fencing and air sports had been vaccinated against influenza. Furthermore, no swimmers were vaccinated against TBE.

During the observation period, there were almost exclusively improvements in vaccination status in each of the 10 sports with the largest number of athletes (**Fig. 2**). The TBE vaccination status of swimmers and the MMR vaccination status of track and field athletes remained unchanged. Skiers had the only decrease in vaccination status among the 10 sports with the largest number of athletes, documented for influenza.

DISCUSSION

Data, showing the vaccination status of elite athletes, are rarely available. Comparisons between different sports are missing. The aim of that study was to give a first overview about vaccination status in German elite athletes. Several German elite athletes are active soldiers as part of the sports supporting system in Germany. Soldiers of the German Armed Forces have to tolerate vaccinations, that are recommended by the STIKO. Elite athletes among them may have limited contact to authorities and physicians of the German Armed Forces due to the possibility to train and compete at local sporting facilities worldwide. So, the question arises if their vaccination status is comparable to that one of regular soldiers or other countries´ elite athletes. Furthermore, the question arises if there are differences, possible reasons for this and whether there are strategies to improve the service for them. A limitation of this study is the huge range regarding the time the athletes served in the German Armed Forces. Lots of athletes are only temporarily member of the

Armed Forces during preparation for important events, e.g. Olympic Games. A planful improvement of vaccination status is therefore hard to achieve. This may lead to lower vaccination rates. In periods of smaller than 12 month it is sometimes not possible to get valid vaccination status for different kinds of vaccination. Nevertheless, we found that vaccination rates overall improved during the observation period because of medical care by the German Armed Forces. A further limitation was, that not all military athletes provided their certificates and so had to be excluded. The risk of selection bias is given, but the results showed comparable status among other soldiers and civilians, so presented data are reasonable.

In case of diphtheria, pertussis, poliomyelitis, and tetanus comparable vaccination rates were found with some higher rates for diphtheria and tetanus. This may be explained by the fact that the STIKO recommends the administration of combined vaccinations against diphtheria and tetanus [1]. Moreover, since 2005 only combined vaccines against diphtheria and tetanus are authorized for use in Germany [23]. The combination from a tetanus and diphtheria with a pertussis and a poliomyelitis vaccine is likewise recommended by the STIKO if indicated [1]. In Germany pertussis vaccine is also available only as a combination vaccine at least combined with tetanus and diphtheria vaccine [24]. A recommendation for pertussis vaccination for all adults existed since 2009 [23]. Simplified vaccination schedules with combination vaccines and the resulting better compliance realized higher vaccination statuses, detectable in this study population, too [25].

In a study of Italian amateur basketball players, the tetanus vaccination status was 73% [19]. Regular German recruits had a tetanus vaccination status of 57% at recruitment [20]. A systematic review showed vaccination rates against tetanus of 94.4% for soldiers in different countries [21]. However, the data was collected by questioning or via the seroprevalence. In addition, the study population consisted largely of recruits and some civilians. Comparable to the normal population, 75.6% of the study participants had at least one vaccination against tetanus in the last 10 years [26]. In our study 61.5% of the elite athletes showed a valid vaccination status at the time of entry and 78.1% at the time of data collection. Hence, there is a higher value among athletes of the German armed forces compared to the German population, German recruits, or other athletes.

In case of hepatitis B vaccination, we observed the strongest improvement. A possible reason may be the lack of a recommendation for a booster in adulthood, which was required in the German Armed Forces for work-related reasons. Although hepatitis A vaccination was also required for soldiers, there is no general vaccination recommendation for civilians in Germany [1]. This was the vaccination where the fewest deteriorations were noticed. Overall, the vaccination status for both vaccines was not very different despite the different recommendations. On the other hand, a study of young recruits found a significant difference in valid vaccination status for hepatitis A at 7% and hepatitis B at 16% [20]. In comparison, soldiers in different countries showed higher vaccination rates of a weighted average of 11.9% for hepatitis A and 41.5% for hepatitis B [21]. Within the normal population, at least one vaccination against hepatitis A was documented in 27.4% and against hepatitis B in 32.9% of the study participants [27]. We obtained relatively high rates for valid vaccination status at the time of data collection with 51.0% for hepatitis A and 59.4% for hepatitis B. Our study therefore showed much higher vaccination rates for both hepatitis A and hepatitis B compared to the German population and other soldiers.

Observed rates of influenza vaccination were low with 3.0% at the time of entry and 18.1% at the time data collection. A study of Saudi Arabian soldiers showed a vaccination rate of 17.8% [28]. In comparison, a study of young Israeli recruits showed a vaccination rate of 48.5% [29]. The results of these 2 studies, however, were both based on interviews. Compared to the time of data collection, similar results for influenza vaccination status with 21.8% in 2010/ 2011 and 17.7% in 2011/ 2012 were shown among adults in Germany [26]. The STIKO recommended vaccination only for persons aged 60 plus, pregnant women, persons with a correspondingly high risk of infection, or for occupational reasons [1]. These criteria were less relevant for athletes and could explain the low vaccination status at the time of recruitment. German soldiers should be vaccinated against influenza. Consequently, the athletes as members of the German Armed Forces should be vaccinated against influenza as well, which may explain the significant increase in the vaccination status. Despite the significant increase, however, too many athletes are still not vaccinated despite the existing obligation. A booster vaccination was necessary annually and required correspondingly close monitoring. This may be one reason why influenza vaccination status was that low. In addition, many different psychological, contextual, sociodemographic, and physical barriers that inhibited annual influenza vaccination were already identified. For example, lower physician contacts and the fear of side effects played an important role [30]. Side effects can have influence on training or competition absence. Local reactions due to vaccination are described as the most frequent side effect among athletes with no differences to control groups [31]. To minimize training absences, athletes should be vaccinated in the off-season or shortly after a training session [14]. Delaying vaccination has no significant effect on the humoral and cellular immune response, but it does prolong possible training absences [31]. In order to prevent complications, athletes should take a break from high intensity training for 2 or 3 days after vaccination [14]. If planned well, there will be no additional training losses [14,31].

Another reason for low vaccination rates at the time of entry could be the recommendation of the German Robert Koch Institute. For example, vaccination against TBE was only recommended for people living or staying in risk areas designated by the European Commission. This results in local varying vaccination recommendations in Germany [1]. Furthermore, initial immunization against TBE usually required 3 doses of vaccine at intervals of up to twelve months. Boosters have to be performed every 3 to 5 years [1]. These complex dosing schedules generated low compliance and resulting low vaccination coverage rates in the general population [32]. Thus, basic immunization and maintenance of vaccination status required relatively close monitoring. Simplified vaccination schedules and extended intervals for booster vaccinations have therefore been controversially discussed for some time [33]. Regarding German adults there was a comparable vaccination status for TBE (29.4%) as in our study at data collection (25.5%) [27]. Comparative data of young recruits in Germany showed a much lower vaccination rate of only 2% [20]. TBE showed comparable low levels of vaccination status as influenza. TBE and influenza required frequent administration to maintain a valid vaccination status. Thus, lower vaccination status was shown for vaccinations that need to be repeated more frequently.

In 1991 STIKO recommended that children should be vaccinated with the MMR vaccine twice [34]. Since 2020, all children have to be vaccinated to enter preschool, kindergarten or elementary school. In addition, people born after 1970 working in medical facilities or community shelters must be vaccinated, too. Every measles vaccine licensed on the German market, is at least a combination with mumps and rubella (MMR) [22]. The MMR vaccination is thus the only mandatory vaccination in Germany [35]. The already high MMR vaccination status changed only little during the observation period. Soldiers from different countries also showed a vaccination rate of a weighted average of just more than 80% for the individual vaccinations mumps, measles and rubella [21]. Another study showed seronegativity of 10.3% for mumps, 10.3% for measles and 29.6% for rubella in American baseball and basketball players [36]. In contrast, an older observation showed much lower rate for 2 MMR vaccinations in a lifetime, with 39.5% in a population younger than 20 years, 11.8% in the 20–29 year old and 2.9% in the 30–39 year old population [37]. Compared to the German population, the vaccination rate in our study was therefore significantly higher, although it was comparable to that of other soldiers and athletes around the world.

No sex-specific differences were found in the population studied here. In contrast, there were sex-specific differences in the vaccination status of German adults [27]. In particular, men were significantly more frequently vaccinated against tetanus than women. Women, on the other hand, were significantly more frequently vaccinated against diphtheria. The target population there, was the population aged 18 to 79 living in Germany and was thus significantly less specific than our population [27].

At the time of recruitment, vaccination status correlated negatively with age only for diphtheria, pertussis, poliomyelitis, and tetanus. A booster for these 4 vaccinations should be administered in adolescence. The basic immunization should have been completed in the first year of life [1]. With a mean age of 20.6 years at the time of recruitment, this booster vaccination was perhaps frequently not applied. At the time of data collection hepatitis A was the only vaccination where vaccination status improved significantly with increasing age. Influenza, MMR, and pertussis correlated negatively with increasing age at the time of data collection. For MMR, no booster vaccination was necessary. A booster vaccination for pertussis was recommended in adulthood at the next necessary diphtheria or tetanus vaccination [1]. With increasing age, this may have been missed more frequently or the booster for diphtheria and tetanus was administered without a pertussis vaccine. In comparison vaccination rates among German adults dropped with increasing age. The only exception is the influenza vaccination, where vaccination rates increase with rising age [27].

The changes within the 10 compared sports were comparable to the changes of the whole study population. Comparing the groups with each other directly, significant differences could be seen. A relation between vaccination status and performed sports could therefore be shown. The visible differences could be due to missing vaccinations that may be the result of limited contact with authorities and doctors of the German Armed Forces and due to complex vaccination schedules or the frequent need to repeat the respective vaccinations what can be a problem because of home based training and competitions far away from supporting military bases. The fear of possible side effects that affects the performance level may have a negative impact, too. Internal guidelines for vaccination of German elite athletes recommend vaccination in the off season as recommended by other authors [18]. That limits the time for availability of athletes and supporting staff. To prevent invalid vaccination rates due to fear of side effects, it could be necessary to provide more counselling to the athletes [38]. Therefore, the commitment of team physicians could have a positive or negative impact on the medical care provided. These effects could not be investigated due to the retrospective design of this study, what is a further limitation of this study. So, preventive aspects should be respected by the caring team physicians, too. Among the annual preventive assessment, it is mandatory to check the vaccination status. More information about the benefits of vaccinations could be provided here. However, currently there are no negative consequences if the vaccination status is invalid. To get a better handling, disciplinary responsibility could also be centralized to enable better influence and control of the vaccination status. This would offer better opportunities for care to the Bundeswehr Center of Sports Medicine with better access to vaccination monitoring. In addition, the introduction of a digital patient file would enable better access to information and central administration. The preventive assessment once a year could be a possibility to evaluate vaccination status and the consequences of evidence-based counseling in a prospective way.

This study provided a first overview about the vaccination status among elite athletes in the German Armed Forces where possible sport specific differences were observed. There were apparently vaccination gaps. Compared to other studies of athletes and soldiers worldwide, the vaccination status of athletes in the German Armed Forces was comparable or even better. The vaccination gaps for the indication-based vaccinations were higher than for the standard vaccinations at the beginning of the observation. Additionally, worse vaccination statuses were evident for vaccinations that had to be repeated more frequently. Most of the athletes showed improvement in their immunization status during the medical support provided by the German Armed Forces. So military service can possibly be a positive predictor for better vaccination status. However, a complete vaccination gap closure during military medical care does not occur either and further consulting and reconnaissance work is necessary.

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

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