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Evaluation of a Mobile Derived 22-Lead Resting Vector ECG in Sports Medicine

Evaluierung eines mobil abgeleiteten 22-Kanal-Ruhe-Vektor-EKGs in der sportmedizinischen Diagnostik und Betreuung

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Summary

- **Background and rationale:** Resting ECG is an essential diagnostic tool in sports medicine. Modern mobile 22-lead Vector ECG device (V-ECG) using only four electrodes has become available to record ECG via mobile devices. In order to implement the V ECG in sports medicine, it is essential that the V-ECG is diagnostically equal to the standard 12-lead resting ECG (R-ECG). This study was designed to present a head-to-head comparison of the V-ECG with the R-ECG in elite athletes.
- **Methods:** In 102 adult eliteathletes the V-ECG was recorded additionally to the R-ECG. These ECGs were compared in standard parameters and in the international criteria of electrocardiographic interpretation in athletes.
- **Results:** Differences were registered in the cardiac axis, absolute QRS amplitudes, signs of ventricular hypertrophy, R/S ratio and polarity of the T wave. Consequently, differences in sports related ECG findings (increased QRS voltage, incomplete right bundle branch block, T wave inversion and pathologic Q wave) were observed.
- **Summary:** Due to the simple handling, V-ECG is a technically beneficial method of ECG registration. At the moment, it can only be used as a supplement to the R-ECG in sports medicine. It is essential that the characteristic differences are always considered when interpreting the V ECG.

Zusammenfassung

- **Hintergrund und Rationale:** Das Ruhe-EKG ist ein wichtiges diagnostisches Instrument in der Sportmedizin. Ein modernes mobiles 22-Kanal-Vektor-EKG-Gerät (V-EKG), das mit nur vier Elektroden auskommt, ist inzwischen verfügbar, um das EKG mithilfe mobiler Endgeräte aufzuzeichnen. Für den Einsatz des V-EKGs in der Sportmedizin ist es unerlässlich, dass das V-EKG diagnostisch gleichwertig mit dem standardmäßigen 12-Kanal-Ruhe-EKG (R EKG) ist. In dieser Studie wurde ein direkter Vergleich zwischen dem V-EKG und dem R-EKG bei Spitzensportlern durchgeführt.
- **Methoden:** Bei 102 erwachsenen Spitzensportlern wurde das V-EKG zusätzlich zum R-EKG aufgezeichnet. Diese EKGs wurden anhand von Standardparametern und den internationalen Kriterien der elektrokardiographischen Interpretation bei Sportlern verglichen.
- **Ergebnisse:** Es wurden Unterschiede in Bezug auf die Herzachsen, die absoluten QRS-Amplituden, die Zeichen der ventrikulären Hypertrophie, des R/S-Verhältnisses und der Polarität der T-Welle festgestellt. Folglich wurden auch Unterschiede bei den sportbezogenen EKG-Befunden (erhöhte QRS-Amplitude, inkompletter Rechtsschenkelblock, T-Wellen-Inversion und pathologische Q-Welle) festgestellt.
- **Zusammenfassung:** Das V-EKG ist aufgrund der einfachen Handhabung eine technisch vorteilhafte Methode der EKG-Registrierung. In der Sportmedizin kann es zurzeit als Ergänzung zum R-EKG eingesetzt werden. Bei der Interpretation des V-EKGs ist die Berücksichtigung der charakteristischen Unterschiede unabdingbar.

KEY WORDS:
International Criteria of Electrocardiographic Interpretation in Athletes, Preparticipation Evaluation in Athletes, Mobile Device, Sudden Cardiac Death, Sports Cardiology

SCHLÜSSELWÖRTER:
Internationale Kriterien der EKG-Interpretation bei Sportlern, sportmedizinische Vorsorgeuntersuchung, mobiles Endgerät, plötzlicher Herztod, Sportkardiologie

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Introduction

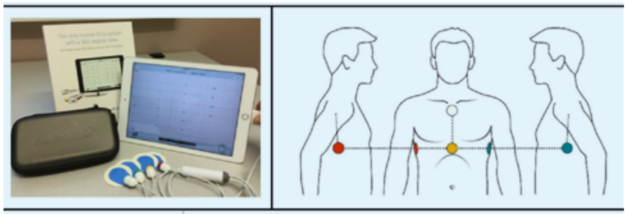
Physical activity and sports have a series of positive effects on health, on quality of life and on life expectancy (10, 12, 18). However, there is a temporarily increased risk of cardiac events in the acute situation of physical activity, such as sudden cardiac death (13). The cardiovascular system is particularly vulnerable under physical stress due to various physical adaption processes (14, 15). If in addition, the athlete has a congenital or acquired underlying heart pathology, physical activity and sports can trigger a cardiac event (11).

In order to identify potentially endangered athletes at an early stage and to minimize the risk of cardiac events, preparticipation screening is recommended. The only mandatory diagnostic examination for leisure and competitive athletes is currently the 12-lead resting ECG derived with ten electrodes (19, 20). This 12-lead resting ECG is interpreted in sports medicine using the international criteria for electrocardiographic interpretation in athletes (2017), comprising normal, borderline and abnormal ECG findings (7).

Recently, a modern portable Vector ECG device has become available requiring only four electrodes to derive a 22-lead resting Vector ECG (V-ECG) via a mobile device (smartphone, tablet) in one synchronous measurement. This V-ECG device offers multiple advantages for sports medical diagnostic and support, especially on site in training and competition. The main advantages are the portable size, its simple handling, the reduced number of four electrodes, which can be attached precisely and quickly to prominent areas of the thorax, and the ECG recording via a mobile device, that can also be performed by non-medical persons. The V-ECG device and the position of the electrodes are shown in figure 1. The leads R, M and L are derived directly. Using an algorithm, the 22-lead V-ECG is reconstructed. In order to be able to use the V-ECG in sports medicine, clinical and diagnostic equivalence to the 12-lead resting ECG (R-ECG) is essential. It must be ensured that no pathological ECG findings are missed in the V-ECG that could have been recognized in the R-ECG. To this end, this study was designed as a head-to-head comparison of the V ECG with the R ECG on a selected group of athletes. The comparison was carried out with the following objectives:

1. To evaluate the differences between the V-ECG and the R-ECG in cardiological standard parameters
2. To evaluate if the sports-induced international criteria of electrocardiographic interpretation in athletes (normal, borderline, abnormal ECG findings) are detected reliably and comparably in the V-ECG and the R-ECG.

Based on the study results, the V-ECG could possibly be implemented in selected groups of athletes as a supplement or even as an alternative to the R-ECG.



Electrode		Position
E	yellow	Anterior midline, distal end of the sternum
A	green	Left middle axillary line, distal end of the sternum
S	white	Jugulum
I	red	Right middle axillary line, distal end of the sternum

Lead	Potential between	
R	I (red)	S (white)
M	E (yellow)	S (white)
L	A (green)	S (white)

Figure 1
22 lead resting vector ECG and position of the electrodes (adapted from (16)).

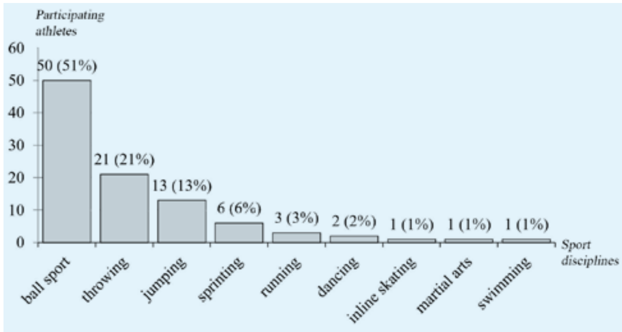


Figure 2
Sport disciplines of the participating athletes. Ball sport: handball, soccer, volleyball, fistball; throwing: discus, hammer, javelin, shot put; jumping: long jump, high jump, triple jump, pole vault; sprinting: sprint, long sprint, hurdle sprint; running: middle distance, long distance, steeplchase; martial arts: wrestling. Two participating athletes competed in two diciplines. Values rounded.

Material and Methods

In this prospective observational study, 102 adult elite athletes (either top athletes of the respective federation, professional status or a comparable level) presenting for routine preparticipation screening were recruited consecutively. The athletes trained regularly with known scope of training in an Olympic competitive sport. For each athlete a V-ECG and a R-ECG was recorded. To derive the V-ECG, the V-ECG device CardioSecur Pro A00053 (MedSystems GmbH, Frankfurt am Main, Germany) and the mobile device iPad 5th generation A1822 (Apple Inc., Infinite Loop, Cupertino, CA, USA) were used. To derive the R-ECG, the ECG device Custo Cardio 200 with the software Custo Diagnostic, version 4.4.12 - 4.6.8 (Custo med GmbH, Ottobrunn, Germany) were utilized. These ECGs were compared in cardiological standard parameters (heart rhythm, heart rate, cardiac axis, raw ECG signal, signs of ventricular hypertrophy, R/S ratio) and in terms of the international criteria of electrocardiographic interpretation in athletes, comprising normal, borderline and abnormal ECG findings.

The study was approved by the local Ethics committee and conducted in accordance with the ethical standards of the declaration of Helsinki. All participants gave informed written consent prior to inclusion into the study.

Table 1
Baseline characteristics of the participating athletes. Mean=arithmetic mean, SD=standard deviation, BMI=body mass index.

CHARACTERISTIC	MEAN ± SD	RANGE
Age [years]	24.2 ± 4.1	18 - 37
Height [cm]	184.5 ± 10.7	160 - 207
Body weight [kg]	83.9 ± 19.6	47 - 130
BMI [kg/m²]	24.3 ± 3.6	18.1 - 33.3
Body fat percentage [%]	13.8 ± 6.3	3.2 - 30.1

Statistical Analysis

Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) and JMP (SAS Institute Inc, Cary, NC, USA) were used for data acquisition and analysis. The descriptive comparison in categorial parameters was performed by absolute and percentage numbers and by modal values. Agreement in categorial parameters was measured by the absolute and relative number of ECGs that showed the same parameter. Continuous parameters were tested for normality by evaluating the Shapiro-Wilk test, skewness and kurtosis. Normally distributed cont-

Table 2

Concordance analyses of the categorial cardiological standard parameters. 95 % -CI: 95 % -confidence interval; P-value H0: κ=0 (one-sided). Values rounded. Agreement: κ < 0: less than expected by chance; κ < 0,20: poor; κ ∈ [0,21; 0,40]: fair; κ ∈ [0,41; 0,60]: moderate; κ ∈ [0,61; 0,80]: good; κ ∈ [0,81; 1]: very good.

PARAMETER	COHEN'S KAPPA COEFFICIENT κ	95 % -CI	P-VALUE	AGREEMENT
1. Heart rhythm	0.64	0.48 – 0.80	< 0.0001	good
2. Cardiac axis	0.41	0.23 – 0.59	< 0.0001	moderate
3. R/S ratio	-0.04	-0.14 – 0.05	0.20	less than expected by chance
4. Polarity of the T wave				
Lead				
I	-0.02	-0.04 – 0.00	0.4040	less than expected by chance
II	0.32	-0.18 – 0.81	0.0005	fair
III	0.33	0.12 - 0.54	< 0.0001	fair
aVR	calculation impossible due to the formula			
aVL	0.19	0.04 - 0.34	0.0070	poor
aVF	0.07	-0.16 - 0.29	0.2062	poor
V1	0.01	-0.09 - 0.10	0.4425	poor
V2	0.08	-0.06 - 0.23	0.1040	poor
V3	0.12	-0.15 - 0.38	0.0677	poor
V4	-0.02	-0.04 – 0.00	0.3888	less than expected by chance
V5	-0.02	-0.03 -0.00	0.4217	less than expected by chance
V6	calculation impossible due to the formula			

Table 4

Concordance analyses of the international criteria of electrocardiographic interpretation in athletes. 95 % -CI: 95 % -confidence interval. P-value H0: κ = 0 (one-sided). Values rounded. Agreement: κ < 0: less than expected by chance; κ < 0,20: poor; κ ∈ [0,21; 0,40]: fair; κ ∈ [0,41; 0,60]: moderate; κ ∈ [0,61; 0,80]: good; κ ∈ [0,81; 1]: very good.

CRITERIA	COHEN'S KAPPA COEFFICIENT κ	95 % -CI	P-VALUE	AGREEMENT
Normal ECG finding				
Increased QRS voltage	0.49	0.21 – 0.76	< 0.0001	moderate
Incomplete right bundle branch block	-0.02	-0.06 – 0.02	0.23	less than expected by chance
Early repolarisation	0.67	0.45 – 0.88	< 0.0001	good
Sinus bradycardia	0.65	0.49 – 0.80	< 0.0001	good
Sinus arrhythmia	0.61	0.42 – 0.81	< 0.0001	good
Ectopic atrial rhtythm	0.70	0.55 – 0.85	< 0.0001	good
Junctional escape rhythm	1	1	< 0.0001	very good
1° AV block	0.66	0.22 – 1	< 0.0001	good
Borderline ECG finding				
Left atrial enlargement	0.63	0.38 – 0.88	< 0.0001	good
Right atrial enlargement	0.43	0.02 – 0.83	< 0.0001	moderate
Abnormal ECG finding				
T wave inversion	0.54	0.21 – 0.86	< 0.0001	moderate
Epsilon waves	1	1	< 0.0001	complete agreement

inuous parameters were compared descriptively with arithmetic mean ± standard deviation, minimum and maximum. The agreement was examined by calculating arithmetic mean ± standard deviation, minimum and maximum of the absolute differences (D = parameter(V-ECG) – parameter(R-ECG)). Non-normally distributed parameters were compared by median, interquartile range, minimum and maximum. The agreement was described by median, interquartile range, minimum and maximum of the absolute differences.

Concordance of categorial parameters was analyzed by means of the Cohen's kappa coefficient (κ). The interpretation of the p-value was based on the significance level α = 0.05 of the one-sided test of the Cohen's kappa coefficient (H0: κ = 0) (1, 5). The concordance of continuous parameters was analyzed according to Bland and Altman by the mean difference or median and the 95 % -limits of agreement (2, 3).

Results

The ECGs were recorded in 102 athletes. Due to insufficient ECG quality, the ECGs of six athletes had to be excluded. Consequently, 96 athletes (38 female, 58 male, ethnicity 91 white, 5 black) participated in the study. Baseline characteristics and sport disciplines of these athletes are shown in table 1 and figure 2. Athletes trained for a total of 15.05 ± 5.89 h per week since 13.39 ± 4.67 years. They did not have any previous cardiac diseases resulting in restriction from competitive sports.

Evaluation of the Cardiological Standard Parameters

The V-ECG closely resembled the R-ECG in cardiological standard parameters. The statistical indicators of the concordance analyses of the categorial cardiological standard parameters are illustrated in table 2. Cohen's kappa coefficient could not be calculated for the polarity of the T wave in leads aVR and V6 due to the formula. In lead aVR the polarity of the T wave in the V-ECG was 100 % negative and in lead V6 the polarity of the T wave in the R-ECG was 100 % positive. The concordance analyses of the amplitudes of the Q waves, the R waves, the R' waves, the S waves and the QS waves were performed according to Bland and Altman for the twelve standard leads, which results in a total of 60 analyses. Table 3 (see supplemental material online) shows the statistical indicators of the 45 Bland-Altman analyses, in which the amplitudes of the respective waves were not equal to 0 mV in the ECGs of three or more athletes. If the distribution of the differences of the V-ECG and the R-ECG was normal, the analyses were carried out parametrically. If the distribution was not normal, they were additionally performed non-parametrically. The final analyses were performed graphically, using the statistical indicators shown in table 3 (see supplemental material online). To illustrate how these analyses were carried out, figure 3 represents the Bland-Altman plots of the R waves of the limb leads. The other analyses were carried out accordingly. As demonstrated in table 2 and 3 and figure 3, the main characteristic differences between the V-ECG and the R-ECG were registered in the cardiac axis, absolute amplitudes, signs of ventricular hypertrophy, R/S ratio and polarity of the T wave. The absolute amplitudes tended to be higher in the V-ECG. Consequently, the Sokolow-Lyon indices also tended to be higher in the V-ECG. The modal value of the R/S transition in the V-ECG occurred from V4 - V5 and in the R-ECG from V3 - V4.

Evaluation of the Sports-Induced International Criteria of Electrocardiographic Interpretation in Athletes

The V-ECG closely resembled the R-ECG in the sports-induced international criteria of electrocardiographic interpretation in athletes. The main statistical parameters of the concordance analyses are demonstrated in table 4. The normal ECG findings are illustrated in green, the borderline ECG findings in yellow and the abnormal ECG findings in red. As it is shown in table 4, the main differences between V-ECG and R-ECG in the international criteria of ECG interpretation in athletes appeared in the normal ECG findings of increased QRS voltage and incomplete right bundle branch block and in the abnormal ECG findings of T wave inversion and pathological Q waves. The increased QRS voltage tended to appear more often in the V-ECG. The incomplete right bundle branch block in the R-ECG tended to be not registered by the V-ECG. Kappa statistics of the agreement in T wave inversion showed a significant moderate agreement. Pathological

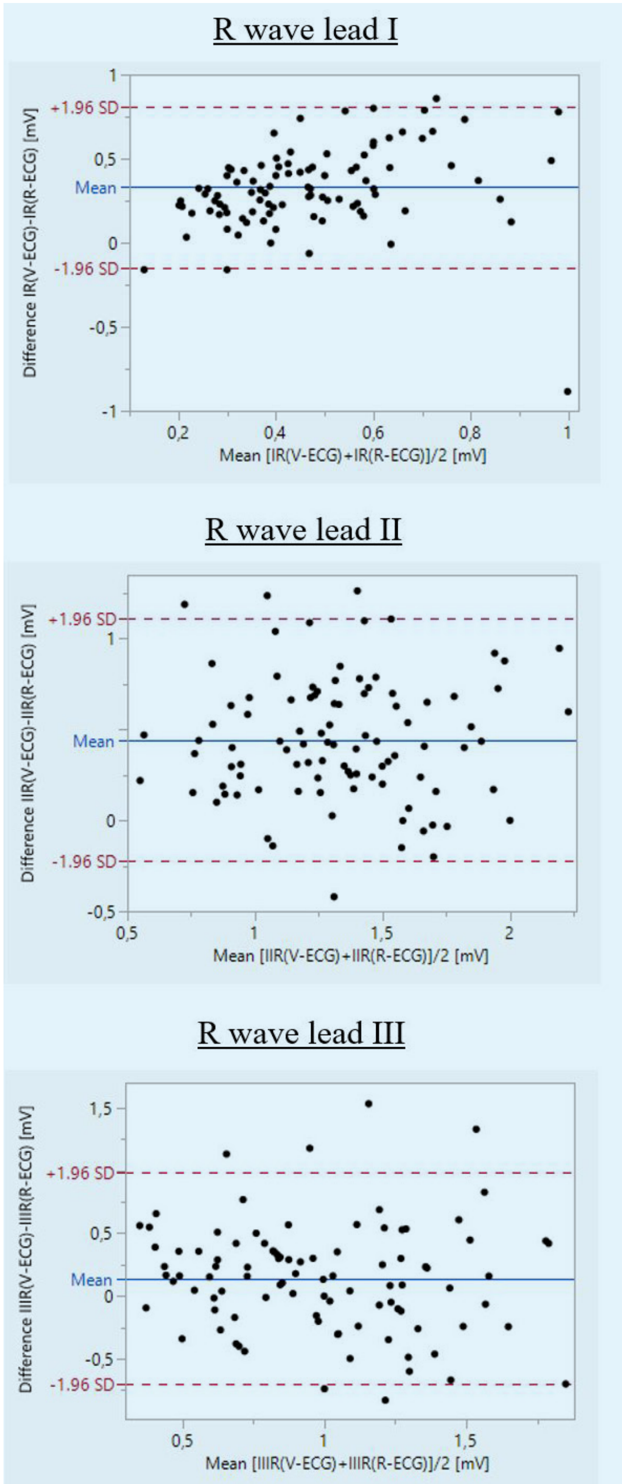


Figure 3

Bland-Altman plots R wave limb leads. Mean: arithmetic mean; SD: standard deviation. Bland-Altman plots show characteristic differences in the amplitudes of the R waves. The mean differences between V-ECG and R-ECG are represented by the continuous blue bold lines. They are > 0 mV, which indicates that the amplitudes of the R waves tended to be higher in the V-ECG. The red dashed lines represent the 95 % -limits of agreement at mean differences ± 1.96 SD. The closer to 0 mV the mean differences and the 95 % -limits of agreement, the better agreement of the compared methods. Systematic over- or underestimation is indicated by mean difference lines and 95 % -limits of agreement far from 0 mV.

Q waves occurred in three athletes only in the V-ECG and not in the R-ECG. Due to the formula, the concordance ›

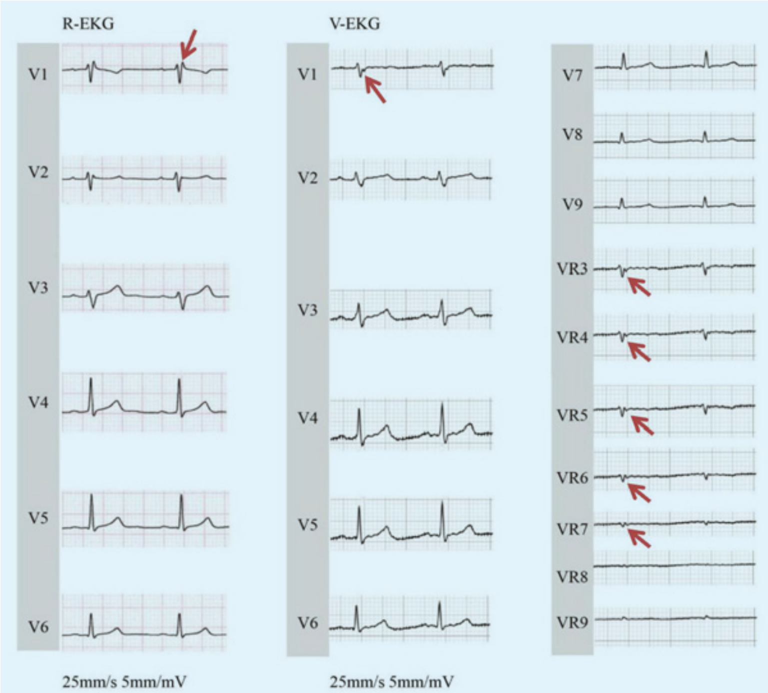


Figure 4

Incomplete right bundle branch block in the 12-lead resting ECG, knot S wave in the corresponding V-ECG Chest, posterior, right precordial leads.

Detection in the V-ECG possible	Detection in the V-ECG conceivable	Detection in the V-ECG limited
• Early repolarisation • Sinus bradycardia • Sinus arrhythmia • Ectopic atrial rhythm • Junctional escape rhythm • 1° AV block	• Mobitz Type I (Wenckebach) 2° AV block	• Increased QRS voltage • Incomplete right bundle branch block
• Left atrial enlargement	• ST segment depression • Complete left bundle branch block • Profound non-specific intraventricular conduction delay • Epsilon waves • Ventricular pre-excitation • Prolonged QT interval • Profound sinus bradycardia • Profound 1° AV block • Mobitz Type II 2° AV block • 3° AV block • Atrial tachyarrhythmias • Premature ventricular contractions • Ventricular arrhythmias	• Left axis deviation • Right axis deviation • Right atrial enlargement • Complete right bundle branch block
		• T wave inversion • Pathological Q waves • Brugada Type 1 pattern

Figure 5

Accuracy of the V-ECG in the international criteria of ECG interpretation in athletes. Not evaluable: Black athletes repolarisation variant, juvenile T wave pattern. Normal ECG findings: coloured green, borderline ECG findings: coloured yellow, abnormal ECG findings: coloured red.

could not be analyzed for the remaining ECG findings, since these ECG findings did not occur either in the V-ECG, or in the R-ECG, or in both.

In some cases, the V-ECG showed a knot of the S wave as a possible correlate to the incomplete right bundle branch block in the R-ECG. Figure 4 demonstrates the ECG signal of a R-ECG with incomplete right bundle branch block and the corresponding V-ECG with a knot of the S wave in leads V1 and VR3 – VR7.

Discussion

This is the first study evaluating the V-ECG in sports medicine. According to this examination, the V-ECG is suitable to interpret the cardiological standard parameters heart rhythm, heart rate, cardiac intervals and the raw ECG signal. For interpretation of the cardiac axis, absolute amplitudes, signs of ventricular hypertrophy, R/S ratio and polarity of the T wave the R-ECG should be preferred. These results closely resemble other results already published before (6, 17, 21).

Moreover, the detection of the sports-induced normal ECG findings of early repolarisation, sinus bradycardia, sinus arrhythmia, ectopic atrial rhythm, junctional escape rhythm, 1° atrioventricular block and the borderline ECG finding of left atrial enlargement in the V ECG is possible. The detection of the normal ECG finding of Mobitz type I (Wenckebach) 2° atrioventricular block and the abnormal ECG findings of ST segment depression, complete left bundle branch block, profound non-specific intraventricular conduction delay, Epsilon waves, ventricular pre-excitation, prolonged QT interval, profound sinus bradycardia, profound 1° atrioventricular block, Mobitz type II 2° atrioventricular block, 3° atrioventricular block, atrial tachyarrhythmias, premature ventricular contractions and ventricular arrhythmias is conceivable. At this point it has to be mentioned that apart from the Epsilon waves, these ECG findings did not occur in the cohort.

Limitations of the V ECG appeared in the detection of the normal ECG findings of increased QRS voltage, incomplete right bundle branch block, the borderline ECG findings of left axis deviation, right axis deviation, right atrial enlargement and complete right bundle branch block and the abnormal ECG findings of T wave inversion and pathological Q waves. Although we did not have any athlete with a Brugada like ECG, it is presumably not possible to detect the Brugada type 1 morphology by the V-ECG, because the V-ECG does not compute the higher placed chest leads, capable of detecting the Brugada morphology.

Summing up, in conjunction with previous published data, the following assessment of the accuracy of the V-ECG in the international criteria of ECG interpretation in athletes, that is shown in figure 5, is made. This assessment is in line with other studies (4, 17, 21). Technically the V-ECG device is beneficial for use in sports medicine in particular due to its simple handling (8, 9). Follow-up studies are necessary to validate the assessment and to implement special criteria for the interpretation of a Vector ECG in athletes.

Limitations

The results of the study are limited because not all international criteria of ECG interpretation in athletes occurred in the cohort, which is explained by the number of athletes studied alone. Therefore, no reliable statement can be made about these ECG findings, whether they would have been detected by the V-ECG. Moreover, it remains unclear whether the results of the V-ECG might not even be superior to the R-ECG, especially with regard to abnormal ECG findings. Possibly, cardiac pathologies could be evident in the V-ECG and the R-ECG, whereas sports-induced ECG findings could be detectable only in the R-ECG but not in the V ECG, or vice versa. Although this hypothesis is highly speculative, it should be investigated in a larger collective. Another limitation results from the collective itself. Only five black athletes and apart from one long distance runner, no endurance athlete like marathon runner or triathlete took part in the study. As some ECG findings (T wave inversion, changes concerning repolarisation) are more common in endurance respectively black athletes, more abnormal ECG findings would likely have occurred by choosing a more diverse collective.

Conclusion

In conclusion, the V-ECG can be currently used in sports medicine as a supplement to the R-ECG. When interpretating the V ECG, the characteristic differences have to always be considered. In addition, certain sports-induced ECG findings have to be interpreted in the R ECG. Furthermore, clinically relevant decisions should currently be made using the R ECG. Moreover, the V-ECG can be used for consecutive ECG examinations. Therefore, it is essential that the V-ECG signal is always compared to the R ECG signal, especially in absolute ECG parameters.

After consecutive evaluation of the V-ECG in following studies and further development and adjustment, the future implementation of the V-ECG with its extended functions as an alternative to the R-ECG in sports medical diagnostic and care might be conceivable.

Practical Applications

At the moment, a practical solution can be to derive the V-ECG and the R-ECG in athletes in initial examination. In consecutive examinations, only the V-ECG has to be registered at first. This V-ECG can be compared to the initially derived V-ECG. Only if there occur significant differences in these V-ECGs, it is necessary to derive the R ECG. With this practical application, it has to always be considered that until now, there is no large-scale study demonstrating the clinical and diagnostic equivalence of the R-ECG and the V-ECG. Formally, at first, the concordance of the V-ECG and the R-ECG had to be proven, that no pathological ECG finding occurring over time is missed in the V-ECG.

Acknowledgment and Indications of Support and Cooperation

The vote of the ethics committee of the University of Tuebingen for the conduction of the study was available at the beginning of the study (number 453/2017BO2, date 19th May, 2017).

Conflict of Interest
The authors have no conflict of interest.

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Sauter L [1], Schellhorn P [1], Niess AM [1], Burgstahler C [1]

Evaluierung eines mobil abgeleiteten 22-Kanal-Ruhe-Vektor-EKGs in der sportmedizinischen Diagnostik und Betreuung

Evaluation of a Mobile Derived 22-Lead Resting Vector ECG in Sports Medicine

ERWEITERTES ABSTRACT

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Design of the Study

Das EKG ist eine fest etablierte, essenzielle und unabdingbare Untersuchungsmethode in der Sportmedizin. Derzeit sind moderne EKG-Geräte verfügbar, die mit vier Elektroden über ein mobiles Endgerät (Smartphone, Tablet) ein 22-Kanal-Ruhe-Vektor-EKG (V-EKG) in einer synchronen Messung ableiten. Speziell aufgrund der einfachen Handhabung ist das V EKG für die sportmedizinische Diagnostik und Betreuung, insbesondere vor Ort im Training und Wettkampf, technisch vorteilhaft. Um es dort einsetzen zu können, muss das V-EKG und das konventionell abgeleitete 12-Kanal-Ruhe-EKG (R-EKG) zwingend diagnostisch gleichwertig sein. Da es bis dato noch keinen direkten Head-to-Head-Vergleich des V-EKGs mit dem R EKG gibt und auch eine Evaluierung des V-EKGs an Sportlern fehlt, wurde vorliegende Studie als prospektive Beobachtungsstudie konzipiert.

Methods

Im Rahmen der Studie wurde bei 102 volljährigen Leistungsportlern ergänzend zum R-EKG das V-EKG abgeleitet. Der Vergleich der EKGs erfolgte in den kardiologischen Standardparametern (Herzrhythmus, Herzfrequenz, Lagetyp, Herzachsen, Verlauf des EKG-Signals, Hypertrophiezeichen, R/S-Umschlag) und in den internationalen Kriterien der EKG-Interpretation bei Sportlern (2017), bestehend aus normalen EKG-Veränderungen, Grenzwertbefunden und abnormalen EKG-Veränderungen.

Results and Discussion

Ergebnis der Studie war die weitestgehende Übereinstimmung des V-EKG mit dem R-EKG. Die charakteristischen Hauptunterschiede zeigten sich im Lagetyp, in den Herzachsen, in den absoluten Amplitudenhöhen, in den Hypertrophiezeichen, im R/S-Umschlag und in der Polarität der T-Welle. Daraus resultierten vornehmlich Unterschiede in den normalen EKG Veränderungen der erhöhten QRS-Amplitude und des inkompletten Rechtsschenkelblocks und den abnormalen EKG-Veränderungen der T-Wellen-Inversion und der pathologischen Q-Zacken. Demnach wird in Zusammenschau mit bereits publizierten Ergebnissen die in Abbildung 1 dargestellte Einschätzung der Genauigkeit der Diagnostik des V-EKGs in den internationalen Kriterien der EKG-Interpretation bei Sportlern vorgenommen.

Somit ist das V-EKG insbesondere aufgrund der einfachen Handhabung eine technisch vorteilhafte Methode der EKG-Registrierung. Derzeit ist der Einsatz als Ergänzung zum R EKG in der sportmedizinischen Diagnostik und Betreuung möglich. Zudem ist es für EKG-Verlaufsuntersuchungen geeignet. Die Interpretation des V-EKGs ist stets in Kenntnis und Berücksichtigung der charakteristischen Unterschiede vorzunehmen. Nach der konsekutiven Evaluierung des V-EKGs in weiterführenden Untersuchungen und der möglichen Anpassung und Weiterentwicklung der Technologie, des Umrechnungsalgorithmus und der Applikation ist ein zukünftiger Einsatz des V-EKGs mit seinen erweiterten Möglichkeiten als Alternative zum R-EKG in der sportmedizinischen Diagnostik und Betreuung in Leistungs- und Breitensport denkbar. ■

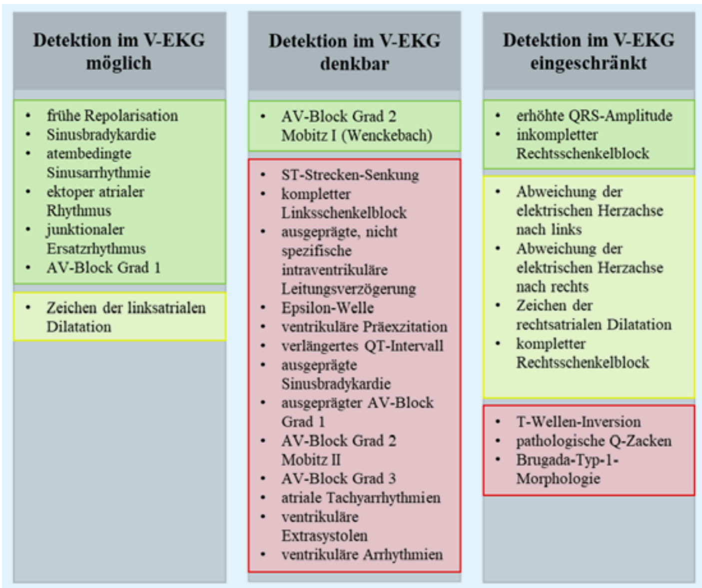

Abbildung 1

Genauigkeit der Diagnostik des V-EKGs in den internationalen Kriterien der EKG-Interpretation bei Sportlern. Nicht evaluierbar: Repolarisationsvariante bei dunkelhäutigen Sportlern, juvenile T-Wellen-Veränderungen. Normale EKG-Veränderungen: grün, Grenzwertbefunde: gelb, abnormale EKG-Veränderungen: rot.

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