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Red blood cell counts and indices in the elderly German population

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Abstract

Background: Data on peripheral blood cell values in older subjects are rare. While hemoglobin (Hb) values are supposed to change with rising age, little is known about reference values for other erythrocytic blood cell counts. This cross-sectional study was initiated to analyze hematologic laboratory parameters among subjects aged ≥60 years.
Methods: This was a retrospective cross-sectional study of outpatient laboratory data between January 1st and December 31st, 2015 originating from a German country-wide laboratory group; inclusion criteria: age ≥60 years, normal C-reactive protein (CRP), transferrin saturation, reticulocytes, lactate dehydrogenase, haptoglobin and soluble transferrin receptor; exclusion criteria: glomerular filtration rate (GFR) <60 mL/min, lack of inclusion criteria; primary objective: assessment of the mean Hb value; secondary objective: assessment of mean values of red blood cell (RBC) counts.
Results: Of 30,611 subjects ≥60 years, 4641 met the inclusion criteria and were thus considered hematologically healthy; the following age groups were formed: 60–69 years (2094), 70–79 years (2171), 80–89 years (360), >90 years (16); median values for male/female subjects were: Hb 15.2/14.0 g/dL, RBC 5.0/4.6/µL, mean cellular volume (MCV) 89/89/fl, mean corpuscular hemoglobin (MCH) 31/30 pg/RBC, mean corpuscular hemoglobin concentration (MCHC) 34/34 g/dL, hematocrit (hct) 44/41%. Statistical evaluation revealed a slight but significant decrease in values over age decades for all parameters except for MCH. However, all values remained within the recommended German Society of Hematology and Oncology (DGHO) reference ranges. Hb values remained above the recommended World Health Organization (WHO) cut-offs for definition of anemia.
Conclusions: The results confirm the WHO reference values and are in accordance with the recommended DGHO reference values and previous results of other study cohorts outside Germany. There seems to be no need for establishing age-specific RBC or erythrocytic reference ranges for subjects >60 years.

Keywords: geriatrics; hematology; reference values.

Introduction

Hematologic disorders like anemia are frequently found in older subjects. For anemia, prevalence rates of >40–50% have been described among geriatric inpatients [1–3]. Hemoglobin (Hb) values are supposed to change with rising age, mirrored by an ongoing debate about the cut-offs for being anemic [4–6]. For the definition of anemia, most of the studies apply the World Health Organization (WHO) reference values of Hb < 12 g/dL (women) and Hb < 13 g/dL (men) [7]. However, the validity of these reference values for older subjects, which have been developed more than 40 years ago by a WHO expert group [7] is controversial [4–6]. Studies on normal Hb values among Canadian and US American cohorts of aged persons have shown that application of WHO criteria for a definition of anemia is not appropriate for these persons, because Hb values varied with age, ethnicity and gender [4, 5, 8]. Corresponding nationwide analyses of normal Hb values among German cohorts of aged persons have been missing so far. Also, there is little known about reference values for erythrocytic parameters in older people. Analysis of red

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cell distribution width (RDW) in older subjects revealed an association between rise of RDW and mortality [9, 10]. A Spanish study group showed a progressive rise in RDW during the last 5 years of life in geriatric patients [11]. Increased RDW levels are therefore assumed to be a mortality risk factor in geriatric patients. However, as reference ranges for older people are unknown, this association remains suggestive.

The primary objective of this study was the analysis of age-specific reference ranges for Hb values of hematologically healthy study subjects >60 years. The secondary objective was the analysis of age-specific reference ranges for erythrocytic blood parameters of hematologically healthy study subjects >60 years.

This study is registered in the German Clinical Trials Registry (DRKS, Freiburg) with No. DRKS00008792. The Ethics Committee of the University Hospital Cologne approved the study (No. 15-282; 27.10.2015). The study was carried out in accordance with the current version of the Declaration of Helsinki of 2013.

Subjects and methods

The analysis was performed based on a cross-sectional study design. We evaluated anemia-related laboratory data of 30,611 outpatients aged ≥60 years from a German laboratory group. The interval of data collection was 12 months, from January 1st, 2015 to December 31st, 2015. All measurements were performed on Sysmex XN 9000 hematology analyzers (Norderstedt, Germany). There was no switch of laboratory device during the time of data collection.

Available anemia-related laboratory data included red blood cell (RBC) and white blood cell counts with subtypes, platelets, reticulocytes, C-reactive protein (CRP), ferritin, glomerular filtration rate (GFR), transaminases and gamma-glutamyltransferase (GT), haptoglobin, lactate dehydrogenase, transferrin and transferrin saturation, transferrin receptor, vitamin B12 and folic acid. The focus of the present study was on analysis of RBCs and erythrocytic indices. Study parameters therefore included Hb (g/dL), RBCs (million/µL), hematocrit (hct, %), mean cellular volume (MCV, fl), mean corpuscular hemoglobin (MCH, pg/RBC), mean corpuscular hemoglobin concentration (MCHC, g/dL) and reticulocytes (reti, ‰). RDW was available as standard deviation (SD) of RBC size (RDWSD, fl). As the focus of the study was on reference values of healthy subjects aged ≥60 years, we selected for the analysis only subjects who showed normal values in all other anemia-related parameters (=inclusion criteria). Reference ranges were based on cut-offs recommended by the German Society of Hematology and Oncology (DGHO) [12, 13].

Exclusion criteria were reduced GFR (mL/min) estimated based on the Chronic Kidney Disease Epidemiology Collaboration (CKD-Epi) formula for subjects ≤70 years (normal values if ≥90 mL/min) [14] and for subjects >70 years estimated based on the Berlin Initiative Study (BIS) formula (normal values ≥60 mL/min) [15].

Subjects included in the study according to inclusion and exclusion criteria were considered hematologically healthy. For age-specific analysis, age groups were formed by age decades as 60–69 years, 70–79 years, 80–89 years and ≥90 years.

Laboratory data was described by mean, SD, median, 2.5th (P2.5) and 97.5th (P97.5) percentiles. Percentiles were

Table 1: Descriptive statistics and percentile for all subjects independent of age and gender.

Parameter	n	Mean	SD	Median	P2.5 [CI]	P97.5 [CI]	Min	Max
Hb	4641	14.58	1.07	14.50	12.60 [12.5–12.7]	16.90 [16.7–17.0]	11.60	18.50
RBC	4816	4.81	0.37	4.80	4.10 [4.0–4.2]	5.60 [5.5–5.7]	3.80	6.20
Hct	4703	0.43	0.03	0.43	0.37 [0.37–0.38]	0.50 [0.49–0.50]	0.35	0.56
MCH	4706	30.3	1.3	30.0	28.0 [27.0–28.0]	33.0 [32.0–34.0]	26.0	34.0
MCHC	5011	33.9	1.0	34.0	32.0 [31.0–32.0]	36.0 [36.0–37.0]	29.0	38.0
MCV	4744	89.3	3.4	89.0	83.0 [82.0–84.0]	96.0 [96.0–97.0]	78.0	104.0

SD, standard deviation; min, minimum; max, maximum; P2.5, 2.5th percentile; P97.5, 97.5th percentile; CI, 95% confidence interval.

Table 2A: Hemoglobin values by age decade and gender.

	n	Mean	SD	Median	P2.5 [CI]	P97.5 [CI]	Min	Max
All females	2498	14.0	0.86	14.00	12.40 [12.3–12.6]	15.80 [15.6–15.9]	11.60	17.10
Females 60–69 years	1104	14.03	0.87	14.00	12.40 [12.3–12.6]	15.80 [15.6–16.1]	11.60	16.50
Females 70–79 years	1159	14.01	0.84	14.00	12.50 [12.3–12.6]	15.70 [15.6–16.0]	11.70	17.10
Females 80–89 years	223	13.93	0.88	13.90	12.32 [11.9–12.7]	15.98 [15.5–16.6]	11.90	16.60
Females ≥90 years	12	13.39	0.74	13.35	12.30 [n.c.]	n.c.	12.30	15.10
All males	2143	15.26	0.90	15.20	13.70 [13.6–13.8]	17.20 [17.0–17.2]	13.00	18.50
Males 60–69 years	990	15.37	0.87	15.30	13.70 [13.5–13.9]	17.20 [17.0–17.4]	13.00	18.10
Males 70–79 years	1012	15.18	0.89	15.10	13.70 [13.5–13.9]	17.20 [17.0–17.4]	13.00	18.50
Males 80–89 years	137	15.02	0.96	14.90	13.54 [n.c.]	17.00 [n.c.]	13.40	18.30
Males ≥90 years	4	14.52	1.27	14.45	13.30 [n.c.]	n.c.	13.30	15.90

Descriptive statistics and percentiles of subjects categorized by gender and age decade. SD, standard deviation; min, minimum; max, maximum; P2.5, 2.5th percentile; P97.5, 97.5th percentile; n.c., not to be calculated; CI, 95% confidence interval.

Table 2B: Red blood cell values by age decade and gender.

	n	Mean	SD	Median	P2.5 [CI]	P97.5 [CI]	Min	Max
All females	2556	4.65	0.32	4.60	4.00 [3.9–4.1]	5.30 [5.2–5.4]	3.80	5.80
Females 60–69 years	1117	4.67	0.31	4.70	4.10 [4.0–4.2]	5.30 [5.2–5.4]	3.80	5.70
Females 70–79 years	1194	4.65	0.33	4.60	4.00 [3.9–4.1]	5.30 [5.2–5.4]	3.80	5.80
Females 80–89 years	233	4.63	0.34	4.60	4.00 [3.9–4.1]]	5.30 [5.2–5.6]]	3.90	5.60
Females ≥90 years	12	4.44	0.32	4.45	4.10 [n.c.]	5.20 [n.c.]	4.10	5.20
All males	2260	4.98	0.34	5.00	4.40 [4.3–4.4]	5.70 [5.6–5.8]	4.20	6.20
Males 60–69 years	1036	5.04	0.34	5.00	4.40 [4.3–4.5]	5.70 [5.6–5.8]	4.20	6.10
Males 70–79 years	1068	4.95	0.34	4.90	4.40 [4.3–4.4]	5.70 [5.6–5.8]	4.20	6.20
Males 80–89 years	152	4.87	0.35	4.80	4.30 [n.c.]	5.60 [n.c.]	4.30	5.80
Males ≥90 years	4	4.88	0.31	4.80	0.37 [n.c.]	0.48 [n.c.]	4.60	5.30

Descriptive statistics and percentiles of subjects categorized by gender and age decade. SD, standard deviation; min, minimum; max, maximum; P2.5, 2.5th percentile; P97.5, 97.5th percentile; n.c., not to be calculated; CI, 95% confidence interval.

calculated according to the International Federation of Clinical Chemistry guidelines on the statistical treatment of reference values [16], together with 95% confidence intervals by normal approximation [17]. The distribution of laboratory data was compared between the age groups using Kolmogorov-Smirnov tests.

Table 2C: Hematocrit by age decade and gender.

	n	Mean	SD	Median	P2.5 [CI]	P97.5 [CI]	Min	Max
All females	2511	0.41	0.02	0.41	0.37 [0.36–0.38]	0.47 [0.46–0.48]	0.35	0.50
Females 60–69 years	1113	0.41	0.02	0.41	0.37 [0.36–0.38]	0.47 [0.46–0.48]	0.35	0.50
Females 70–79 years	1162	0.41	0.02	0.41	0.37 [0.36–0.38]	0.47 [0.46–0.48]	0.35	0.50
Females 80–89 years	224	0.41	0.02	0.41	0.37 [n.c.]	0.48 [n.c.]	0.36	0.50
Females ≥90 years	12	0.39	0.02	0.39	0.36 [n.c.]	0.51 [n.c.]	0.37	0.56
All males	2192	0.44	0.02	0.44	0.40 [0.39–0.40]	0.51 [0.50–0.52]	0.37	0.56
Males 60–69 years	1010	0.44	0.02	0.45	0.40 [0.39–0.41]	0.51 [0.50–0.51]	0.37	0.56
Males 70–79 years	1034	0.44	0.02	0.44	0.40 [0.39–0.41]	0.51 [0.50–0.52]	0.38	0.55
Males 80–89 years	143	0.44	0.03	0.44	0.39 [n.c.]	0.51 [n.c.]	0.38	0.54
Males ≥90 years	5	0.42	0.04	0.41	0.37 [n.c.]	0.48 [n.c.]	0.37	0.48

Descriptive statistics and percentiles of subjects categorized by gender and age decade. SD, standard deviation; min, minimum; max, maximum; P2.5, 2.5th percentile; P97.5, 97.5th percentile; n.c., not to be calculated; CI, 95% confidence interval.

Table 2D: Mean corpuscular hemoglobin values by age decade and gender.

	n	Mean	SD	Median	P2.5 [CI]	P97.5 [CI]	Min	Max
All females	2538	30.1	1.3	30.0	28.0 [27.0–28.0]	33.0 [32.0–33.0]	26.0	34.0
Females 60–69 years	1118	30.1	1.3	30.0	28.0 [27.0–28.0]	33.0 [32.0–34.0]	26.0	34.0
Females 70–79 years	1178	30.1	1.3	30.0	28.0 [27.0–28.0]	32.0 [32.0–33.0]	26.0	34.0
Females 80–89 years	229	30.0	1.3	30.0	27.0 [n.c.]	32.0 [n.c.]	27.0	33.0
Females ≥90 years	13	30.0	1.2	30.0	27.0 [n.c.]	32.0 [n.c.]	27.0	32.0
All males	2168	30.5	1.3	31.0	28.0 [27.0–28.0]	33.0 [32.0–34.0]	26.0	34.0
Males 60–69 years	1003	30.4	1.3	30.0	28.0 [27.0–28.0]	33.0 [32.0–34.0]	26.0	34.0
Males 70–79 years	1023	30.6	1.3	31.0	28.0 [27.0–29.0]	33.0 [32.0–34.0]	27.0	34.0
Males 80–89 years	138	30.6	1.2	30.0	32.0 [n.c.]	36.0 [n.c.]	31.0	37.0
Males ≥90 years	4	29.8	1.0	29.5	32.0 [n.c.]	34.0 [n.c.]	29.0	31.0

Descriptive statistics and percentiles of subjects categorized by gender and age decade. SD, standard deviation; min, minimum; max, maximum; P2.5, 2.5th percentile; P97.5, 97.5th percentile; n.c., not to be calculated; CI, 95% confidence interval.

Results

Of 30,611 cases we excluded 207 for lack of RBC counts. After application of inclusion and exclusion criteria, analysis of RBC counts was performed among the remaining subjects. Overall, the evaluation of study parameters is shown in Table 1. Tables 2A–F show results of analysis by gender and age decades. As values of RDWSD and

Table 2E: Mean corpuscular hemoglobin concentration values by age decade and gender.

	n	Mean	SD	Median	P2.5 [CI]	P97.5 [CI]	Min	Max
All females	2766	33.7	1.0	34.0	32.0 [31.0–32.0]	36.0 [35.0–36.0]	29.0	37.0
Females 60–69 years	1201	33.8	1.0	34.0	32.0 [31.0–32.0]	36.0 [35.0–37.0]	30.0	37.0
Females 70–79 years	1283	33.7	1.0	30.0	32.0 [31.0–32.0]	36.0 [35.0–36.0]	29.0	37.0
Females 80–89 years	263	33.6	1.0	34.0	32.0 [n.c.]	35.0 [n.c.]	31.0	36.0
Females ≥90 years	19	32.9	1.0	33.0	31.0 [n.c.]	35.0 [n.c.]	31.0	35.0
All males	2245	34.1	1.0	34.0	32.0 [31.0–33.0]	36.0 [36.0–37.0]	30.0	38.0
Males 60–69 years	1035	34.2	1.0	34.0	32.0 [31.0–33.0]	36.0 [36.0–37.0]	31.0	38.0
Males 70–79 years	1056	34.1	1.0	31.0	32.0 [31.0–33.0]	36.0 [36.0–37.0]	30.0	37.0
Males 80–89 years	148	33.9	1.1	34.0	32.0 [n.c.]	36.0 [n.c.]	31.0	37.0
Males ≥90 years	6	32.8	0.8	33.0	32.0 [n.c.]	43.0 n.c.]	32.0	34.0

Descriptive statistics and percentiles of subjects categorized by gender and age decade. SD, standard deviation; min, minimum; max, maximum; P2.5, 2.5th percentile; P97.5, 97.5th percentile; n.c., not to be calculated; CI, 95% confidence interval.

Table 2F: Mean cellular volume values by age decade and gender.

	n	Mean	SD	Median	P2.5 [CI]	P97.5 [CI]	Min	Max
All females	2546	89.1	3.4	89.0	83.0 [82.0–84.0]	96.0 [95.0–97.0]	78.0	104.0
Females 60–69 years	1124	89.0	3.4	89.0	83.0 [82.0–84.0]	96.0 [95.0–98.0]	80.0	104.0
Females 70–79 years	1176	89.2	3.3	89.0	83.0 [82.0–84.0]	96.0 [95.0–97.0]	78.0	99.0
Females 80–89 years	233	89.3	3.5	89.0	83.0 [n.c.]	97.0 [n.c.]	80.0	99.0
Females ≥90 years	13	90.8	4.7	90.0	84.0 [n.c.]	102.0 [n.c.]	84.0	102.0
All males	2198	89.5	3.4	89.0	83.0 [82.0–84.0]	97.0 [96.0–98.0]	80.0	102.0
Males 60–69 years	1014	89.1	3.4	89.0	83.0 [82.0–84.0]	96.0 [95.0–98.0]	80.0	102.0
Males 70–79 years	1041	89.8	3.4	90.0	83.0 [82.0–84.0]	97.0 [96.0–98.0]	81.0	102.0
Males 80–89 years	139	90.0	3.2	90.0	84.0 [n.c.]	96.0 [n.c.]	82.0	98.0
Males ≥90 years	4	89.3	3.6	88.5	86.0 [n.c.]	94.0 [n.c.]	86.0	94.0

Descriptive statistics and percentiles of subjects categorized by gender and age decade. SD, standard deviation; min, minimum; max, maximum; P2.5, 2.5th percentile; P97.5, 97.5th percentile; n.c., not to be calculated; CI, 95% confidence interval.

reticulocytes were only rarely and incompletely available (RDWSD in 16 subjects, reticulocytes in 144 subjects), they were not included in further age and gender-specific evaluation. While 2.5th to 97.5th percentiles of study parameters were comparable over age groups in each gender group (Tables 2A–F), the distribution of Hb, hct and RBC

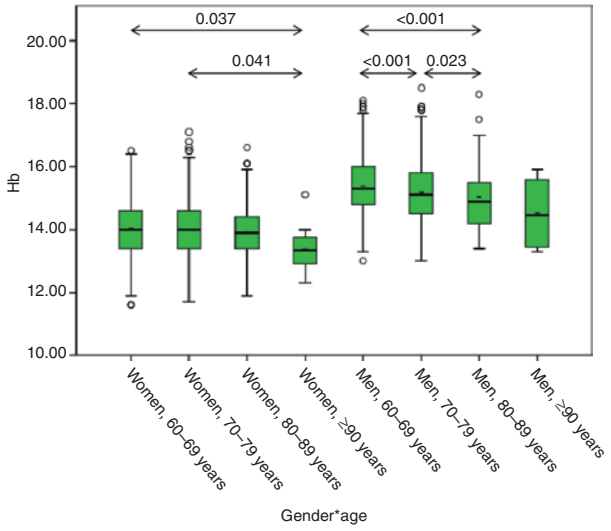

Figure 1: Hemoglobin (Hb) values by gender and age decades; arrows: pairwise comparison based on Kolmogorov-Smirnov tests.

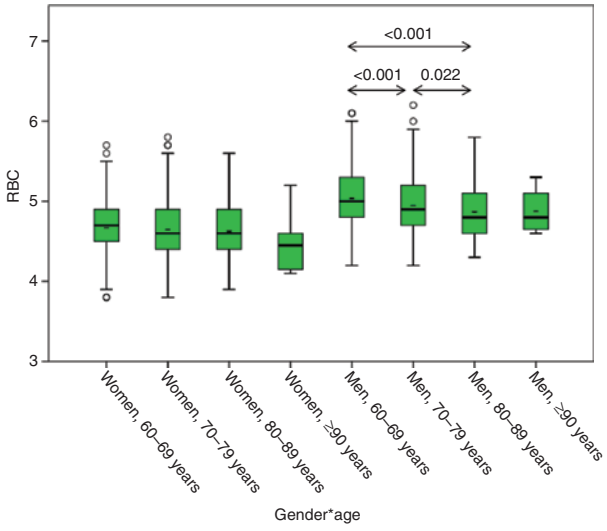

Figure 3: Red blood cell (RBC) values by gender and age decades; arrows: pairwise comparison based on Kolmogorov-Smirnov tests.

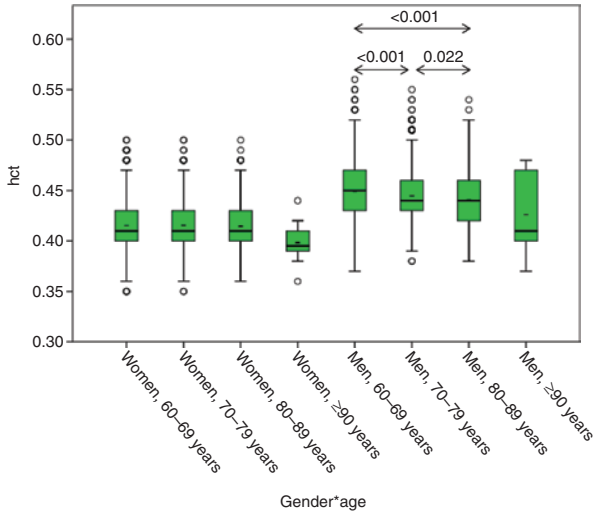

Figure 2: Hematocrit (hct) values by gender and age decades; arrows: pairwise comparison based on Kolmogorov-Smirnov tests.

was significantly different between the age groups independent of gender. Pairwise evaluation is shown separately for men and women in Figures 1–3. For the other study parameters, no significant difference between age groups could be shown.

With regard to the nonagenarians, however, statistical power is limited due to the very small number of subjects in this age decade. Nevertheless, for the sake of completeness, results are presented (Tables 2A–F, Figures 1–3).

Comparison of 2.5th to 97.5th percentile value of study parameters with the recommended DGHO reference ranges [12, 13] for the study parameters revealed accordance (Table 3). In total, 97.5% of Hb values among males and females in this hematologically healthy study population were above WHO cut-offs for definition of anemia [7]. Comparison with previous studies revealed lower Hb values if younger subjects or children were included (Table 3).

Discussion

We have analyzed RBCs and the associated erythrocytic indices in 4641 hematologically healthy outpatients >60 years. So far, the results represent the largest and first nationwide analysis of erythrocytic parameters in a German cohort of older subjects. Interestingly, a previous smaller regional study on blood counts among German subjects from Pomerania showed lower reference ranges for Hb, RBC and hct compared to our study [18] (Table 3). However, this study population also included younger patients (20–79 years), compared to our investigations and the laboratory equipment was older [18]. A recent Canadian analysis of hematologic markers across pediatric, adult and geriatric ages evaluated 11,999 subjects and came to similar results as Ittermann et al. [18]: They revealed dynamic changes in hematologic markers from childhood to adulthood, but constant Hb concentration between 11.9 and 14.8 g/dL for females from 11 to 79 years and Hb concentration between 13.6 and 16.9 g/dL for males from 20 to 79 years [19]. A multiethnic population-based analysis of hematologic parameters from Malaysia included 2440 subjects >19 years and confirmed Hb reference intervals reported by Itterman et al. [18] and Adeli

Table 3: Comparison of study reference intervals with recommended DGHO intervals and previous studies.

Study parameter	Study results for reference intervals (2.5th to 97.5th percentile)	Recommended DGHO reference interval	Recommended WHO reference values (1968)	Itterman et al. [18] (n=2967; 20–79 years)	Adeli et al. [19] (n=11,999; age ranges below)	Ambayya et al. [8] (n=2440; >19 years)	Tsang et al. [20] (n=3654; 49–97 years)
Hemoglobin, g/dL	Females: 12.4–15.8 Males: 13.7–17.2	Females: 12.0–16.0 Males: 13.5–17.5	Females: >12 Males: >13	Females: 11.2–14.6 Males: 12.5–16.4	Females (11–79 years): 11.9–14.8 Males (20–79 years): 13.6–16.9	Females: 11.6–15.1 Males: 11.8–16.9	Females: 12.2–16.2 Males: 13.3–17.6
RBC, /µL	Females: 4.0–5.3 Males: 4.4–5.7	Females: 4.1–5.1 Males: 4.5–5.9	/	Females: 3.6–4.9 Males: 3.9–5.4	Females (15–79 years): 3.8–5.0 Males (50–79): 4.2–5.5	Females: 3.8–5.2 Males: 3.8–5.6	Females: 3.9–5.4 Males: 4.2–5.9
Hematocrit, %	Females: 37–47 Males: 40–51	Females: 36–48 Males: 40–53	Females: 36 Males: 39	Females: 33–43 Males: 37–48	Females (12–79): 35–43 Males (16–79): 40–50	Females: 35.1–44.9 Males: 35.7–48.9	Females: 36–48 Males: 39–51
MCV, fl	Females: 83–96 Males: 83–97	80–96	/	/	82.5–98	80.6–95.5	Females: 80.4–97.6 Males: 79.1–99.0
MCH, pg/RBC	Females: 28–33 Males: 28–33	28–33	/	/	27.6–33.3	26.9–32.3	Females: 26.7–34.5 Males: 27.0–33.7
MCHC, g/dL	Females: 32–36 Males: 32–36	33–36	34	/	32.5–35.2	31.9–35.3	/
Reticulocytes, ‰	n.c.	0.4–1.6	/	/	/	/	/

n.c., not to be calculated.

et al. [19]. Neither of the three studies mentioned considered older patients aged >80 years. Literature on hematologic values for this older patient group >80 years is scarce. An Australian study from 1998 evaluated hematologic parameters of 3654 patients between 49 and 97 years of age [20]. Hematologic reference intervals of their study parameters were confirmed by our results (Table 3), underlining the importance of age-appropriate population subsets for reference interval analysis. Physiologic hormonal changes [21] as well as comorbidities, drug intake [22, 23] or habits like smoking [24] or alcohol consumption [25] can affect hematologic parameters throughout life and may affect parameter ranges. Therefore, the choice of an age-appropriate, healthy study population for the assessment of geriatric reference values is crucial. However, it is challenging because of increasing comorbidities and associated polymedication with older age, a decrease of mobility to take part in the study and, of course, a limited life expectancy. For these reasons we chose a retrospective study design.

There are two important findings of the present study: our study results are in accordance with the recommended ranges for erythrocytic parameters of the DGHO [12, 13]. They also confirm the WHO cut-off values for the definition of anemia [7], as shown additionally in a previous Australian study by Tsang et al. [20]. These findings suggest no need for age-specific hematologic reference ranges for aged subjects >60 years. Nevertheless, our results of Hb ranges do not provide any information about mortality. A previous study on community dwelling Canadian subjects aged >66 years revealed an inverse J-shaped relationship between Hb and all-cause mortality. The lowest risk for mortality occurred at Hb values between 13 and 15 g/dL for women and 14–17 g/dL for men [5]. While our Hb reference ranges for females are slightly lower than those by Culleton et al. [5], our Hb reference ranges for males are in accordance with the findings by Culleton et al. [5]. However, based on our data, we cannot deduce mortality risk.

Our study has a number of limitations: subjects included in the study were only considered to be hematologically healthy, but we had no detailed clinical information about any comorbidity, alcoholism, smoking habits or drug intake. Even though representativity for German population can be assumed, we did not get any information about the ethnicity of the study patients. A further limitation is the small number of >90 years old evaluable subjects included in the study, impeding generally recommended range intervals for this special age group.

One of the main virtues of this study is the large cohort of study patients, allowing a representative insight

into erythrocytic parameters among German subjects >60 years and a deduction of reference ranges; another virtue is the hitherto uniqueness of this epidemiologic study on a German population; the methodical consistency of parameter determination is a further virtue increasing the validity of the study results.

Conclusions

The study results imply no need for establishing age-specific reference ranges for RBCs and their associated indices for subjects >60 years. They confirm the applicability of the WHO cut-off values for the definition of anemia. These findings may facilitate interpretation of erythrocytic laboratory results as well as the detection of anemia in aged subjects >60 years.

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