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Demographic changes in the Polish blood donors eligible for blood donation and screened for transfusion-transmitted infections (2005–2018)

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Summary

Background: *The infection frequency among donors found eligible for donation (based on donor questionnaire and physical examination) and therefore the risk of post-transfusion adverse reactions has been demonstrated to be closely related to donor demographics.*

The aim of the study was to determine the demographic changes among Polish blood donors found eligible for donation and subjected to screening for infectious markers in the years 2005–2018. The results were referred to transfusion safety, and particularly to the risk of transfusion-transmitted infectious agents.

Material and methods: *Subjected to analysis were data collected i.a. to assess the epidemiology of blood-borne infectious agents: the number of screened donors found eligible for donation divided into categories by sex, first and repeat donation as well as age groups (≤ 20, 21–30, 31–40, 41–50, 51–60 and > 60 years). Frequencies (fraction) were expressed as percentage with a 95% confidence interval [95%CI] and the differences — as percentage point (p.p.). The significance of difference ($p < 0.05$) was verified by the Chi-squared test, and the Spearman correlation coefficient (R) was used to assess the trend.*

Results: *Most donors were men (74.07% on average) but in the years 2005–2012 the number of women increased by 7 p.p. up to 27.42% [27.30–27.53%] ($p < 0.05$); by 10.58 p.p among first-time donors and by 7.19 p.p. among repeat donors. The highest frequency of women was observed in the population of the youngest age group (36.02% [35.95–36.09%]) and the lowest among the oldest age group of donors (14.14% [13.80–14.48%]) (difference 21.88 p.p.; $p < 0.05$). The majority were repeat donors (66.78% on average). The frequency of repeat donors increased by a total of 19.83 p.p. ($p < 0.05$): by 20.6 p.p. for men and by 21.15 p.p. for women ($p < 0.05$ for both groups). In all age groups, except the youngest, the majority ($p < 0.05$) were repeat donors. The frequency of repeat donors increased in subsequent age*

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groups — from 36% in the youngest (≤ 20 years) to 87% in the oldest donors (> 60 years). The frequency of donors > 40 years increased by 11.58 p.p. from 37.38% to 48.96%.

Conclusions: *In the years 2005–2018, significant demographic changes were observed in the population of Polish donors; the frequency of women donors and repeat donors increased, with benefit for transfusion safety.*

Key words: blood donors, first time donors, repeat donors, men donors, women donors, age groups, screening tests

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Introduction

The risk of pathogen transmission via blood and blood components has been markedly reduced through implementation of serologic testing for the presence of infection markers prior to every blood donation. Such procedures were implemented in the Polish blood transfusion service (BTS) at the beginning of the 70ies followed by implementation of each donation testing for the presence of HBV infection markers. Since 1987, all blood donors have been screened for the presence of HIV infection markers and since 1994 also for HCV. The turn of the century witnessed the implementation of donor screening with molecular biology methods. In 1999, HCV RNA was implemented for donors of plasma for fractionation and since 2002, HCV RNA screening was applied to all blood donors. In 2005 mandatory testing for RNA HIV and DNA HBV was applied to all blood donors [1]. Transfusion safety is closely related to the demographic characteristics of donors of blood and blood components. It is known that the frequency of detection of transfusion-transmitted infections varies with sex, age, and donor-category — and is usually higher in first-time donors than in repeat donors [1–5]. According to WHO regulations, blood donation should rely mainly on repeat donors because their blood is considered safer [2]. It is also known that demographic characteristics vary between countries and sometimes even between regions of the same country [5–7]. It must be remembered however, that the demographic parameters such as the number of first-time donors and repeat donors may undergo changes. One example of the relationship between demographics and the epidemiology of transfusion-transmitted infections in donors comes from the analyses of infection frequency in individual age groups. For example, in 2005–2015 in Poland, HBV and HCV infections were mostly detected in the youngest group of donors, while HIV infections — in the 21–30 age group and were significantly more frequent among first-time donors than in repeat donors. HIV infections were also more frequent among men than women [1]. The awareness of donor demographics and the current trends may prove useful when planning marketing strategy for blood donation addressed to the low-risk groups for transfusion-transmitted infections.

Aim

The aim of the study was to assess the changes in the demographics of Polish blood donors eligible for blood donation and screened for transfusion-transmitted infections in the period 2005–2018. The results were interpreted in the context of transfusion safety, and in particular — of the risk of transfusion-transmitted infections.

Material and methods

The demographic analysis was based on the data collected by the Institute of Hematology and Transfusion Medicine (IHTM) for the purpose of monitoring the epidemiology of blood-borne infections. For the previous year, all 23 Polish Blood Transfusion Centers (BTCs) are obliged to forward to IHTM the data which include: the number of donations and donors screened for the presence of infection markers categorized according to sex and 6 age groups; ≤ 20, 21–30, 31–40, 41–50, 51–60 and > 60. The analyses were performed for each BTC and for all reported donors divided into groups of first-time and repeat donors. According to current regulations donors < 18 and > 65 years of age are allowed to donate blood only in special circumstances and every time the physician's consent is required. Donors < 18 years old additionally need a written legal guardian consent. First-time blood donors were defined as persons who donate blood in the reporting year for the first time in their lives (regardless of the number of donations donated during that particular year); repeat blood donors were defined as persons who had donated blood also in the previous years. The data were

collected from a uniform template-form prepared by IHTM, sent to the BTCs in 2016 and included in the Announcement of the Minister of Health (tables 16.8.1–16.8.3) [8]. In 2016, the BTCs forwarded to IHTM the template-forms completed for the individual years of the 2005–2016 period and then continued to send completed forms after the end of each reporting year, according to regulations [8]. In the years 2005–2018, we acquired data on a total of 16,411,450 donations collected from 8,092,572 blood donors.

The data was provided annually by each BTC in form of a completed xls sheet, aggregated in Office Excel (Microsoft) and then analysed in Statistica (version 13.3, Tibco, Palo Alto, CA, USA). Frequencies were expressed as percentages with a 95% confidence interval [95% CI]. Significance of differences ($p < 0.05$) was verified by Chi-square test. The Spearman's rank correlation coefficient was used to analyse the trend, with the calculation of the R coefficient and the significance of changes ($p > 0.05$). The value $R = 0$ meant that the variables were not correlated. The value "$0 < + R \leq + 1$" and $p < 0.05$ meant that the observed upward trend was statistically significant. The value of "$-1 \geq R > 0$" and $p < 0.05$ meant that the observed downward trend was statistically significant. When the R values were different (then mentioned above) and $p > 0.05$, no significant upward or downward trend was observed. Differences and changes observed over time were considered statistically significant at $p < 0.05$. The difference between two percentage values was expressed as percentage point (p.p.). The authors of this study use "donors" and "blood donors" in the meaning of a subgroup of people who volunteered to donate blood and components and were screened for transfusion-transmitted infections.

Results

Demographic changes; men vs. women blood donors (2005–2018)

In the period 2005–2018 most Polish blood donors were men — 74.07%, yet significant changes were ongoing (Fig. 1). The frequency of women donors regularly increased: from 20.42% [20.31–20.54%] in the first observation year to 28.37% [28.25–28.48%] in 2015, $p < 0.05$. A continuous increment in the frequency of women donors was observed from 2005 to 2012 ($R = +1$; $p < 0.05$) and ranged from 0.93 p.p. year by year to 1.72 p.p. In the period 2012–2018, the structure did not change significantly ($R = +0.35$; $p > 0.05$), however, there were fluctuations in the percentage of women donors in the last year of the analysis — 27.82% [27.71–27.93%].

Demographic changes; men vs. women in the groups of first-time and repeat blood donors (2005–2018)

Men dominated in both first-time and repeat blood donor populations and were a statistically significant majority in the latter — 77.60% [77.56–77.63%] vs. first-time blood donors — 66.38% [66.32–66.44%], $p < 0.05$.

In the period 2005–2018, age structure and the dynamics of change differed in both donor groups (Figs. 2A and 2B). Among first-time donors, there was a significant ($p < 0.05$) increase in the percentage of women year-on-year by 0.72 p.p. (2008/2007) up to 3.39 p.p. (2009/2008). In total, in the period 2005–2011, the percentage of women in the population of first-time blood donors increased by 10.58 p.p. from 25.70% [25.52–25.88%] to 36.28% [36.07–36.49%], $p < 0.05$. In the later period, the percentage of women increased by a maximum of 2.5 p.p. year on year (until 2017 $p < 0.05$; 2017/2018 $p > 0.05$). The highest percentage of women donors was reported in 2015 (39.74%), and 38.20% in 2018 (Fig. 2A).

For repeat blood donors the change was slightly different. Until 2012 there was a continuous and significant increase in the percentage of women year-on-year ($p < 0.05$) while the subsequent changes (beyond 2013–2015) were insignificant ($p>0.05$). In the group of repeat donors, the min. increase in the percentage of women was by 0.01 p.p. (2013 vs. 2012) and max. by 1.35 p.p. (2007 vs. 2006). In total, in 2005–2012, the frequency of women increased by a total of 7.18 p.p., from 16.29% [16.15–16.44%] to 23.47% [23.35–23.60%] ($p < 0.05$) (Fig. 2B). The change was 3.4 p.p. lower than observed for first-time blood donors.

Throughout the observation period, the difference between the frequency of women in the populations of first-time and repeat blood donors was maintained — from 9.08 p.p. in 2006 to 15.36 p.p. in 2015. During the following time intervals (2005–2008, 2009–2013 and 2014–2018), the percentage of women who donated blood for the first time and repeat women-donors differed significantly ($p < 0.05$) (Fig. 2C).

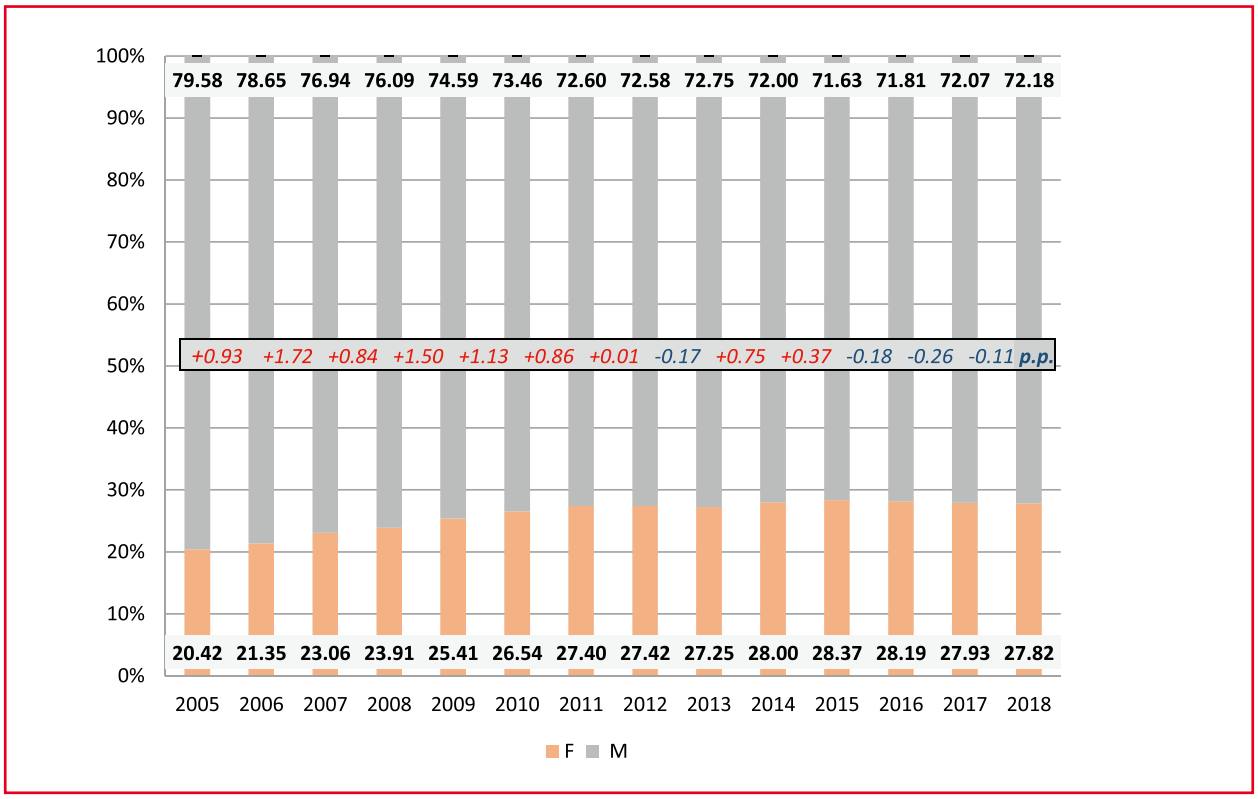

Figure 1. Frequency (%) of females (F) and males (M) among Polish donors found eligible for donation and subjected to screening for infectious markers (2005–2018); p.p. — percentage point

Table 1. Sex structure (%) by age groups of Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) (cumulative data)

Age group	Numer of donors			Donor frequency (%)	
	All	Women	Men	Women [95% CI]	Men [95% CI]
≤ 20	1 831 885	659 790	1 172 095	36.02 [35.95–36.09]	63.98 [63.91–64.05]
21–30	3 015 039	780 298	2 234 741	25.88 [25.83–25.93]	74.12 [74.07–74.17]
31–40	1 793 221	387 957	1 405 264	21.63 [21.57–21.69]	78.37 [78.31–78.43]
41–50	987 250	202 230	785 020	20.48 [20.40–20.56]	79.52 [79.44–79.60]
51–60	424 922	78 738	346 184	18.53 [18.41–18.65]	81.47 [81.35–81.59]
> 60	40 255	5691	34 564	14.14 [13.80–14.48]	85.86 [85.52–86.20]

CI — *confidence interval*

Demographic changes; men vs. women in age groups (2005–2018)

Table 1 demonstrates the percentage of men and women in individual age groups of Polish blood donors in the period 2005–2018. The highest percentage of women (36.02% [35.95–36.09%]) was observed among the youngest blood donors aged ≤ 20 and the lowest (14.14% [13.80–14.48%]) among blood donors aged > 60 — the difference was 21.88 p.p. ($p < 0.05$).

The percentage of men donors in each of the six age groups was higher than that of women and increased with age, from 63.98% in the group of the youngest blood donors to 85.86% in the oldest group ($p < 0.05$; $R = +0.94$). An opposite trend was observed for women — the percentage continuously decreased with age, from 36.02% in the group of blood donors ≤ 20 to 14.14% in the group > 60 ($p < 0.05$; $R = -0.94$) (Table 1).

A significant increase in the percentage of women donors was reported in all age groups

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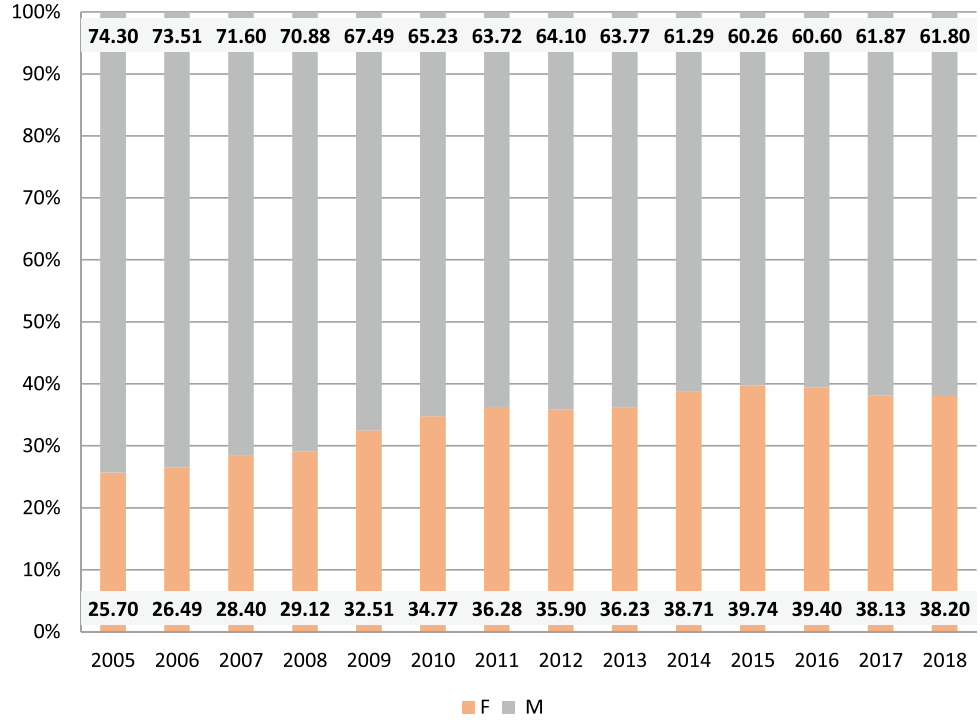
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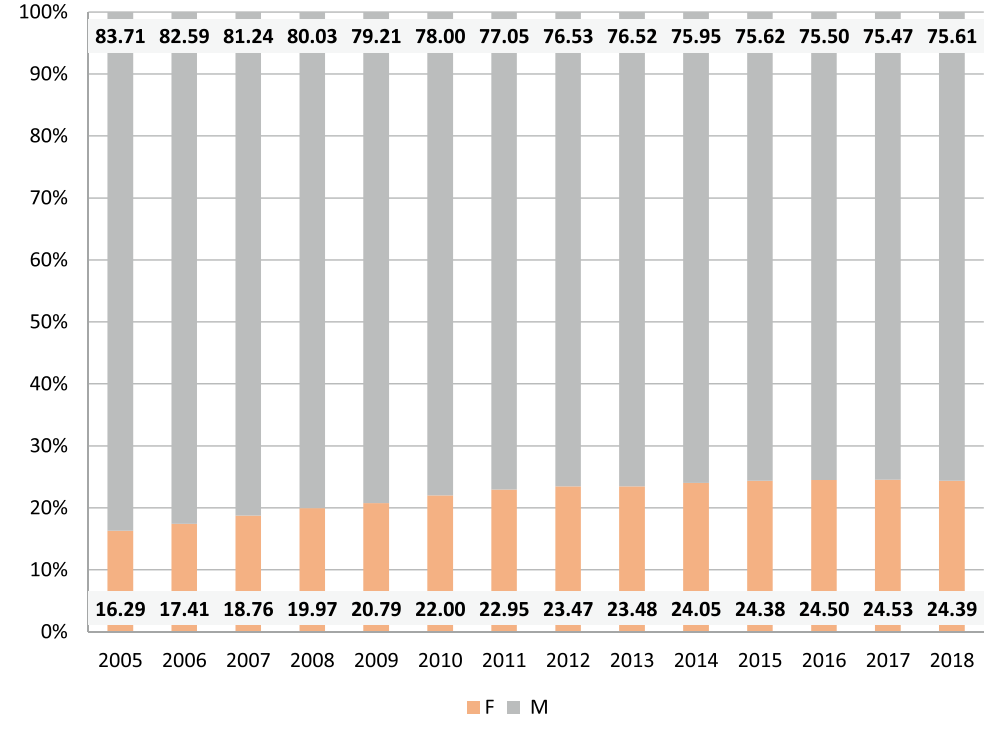
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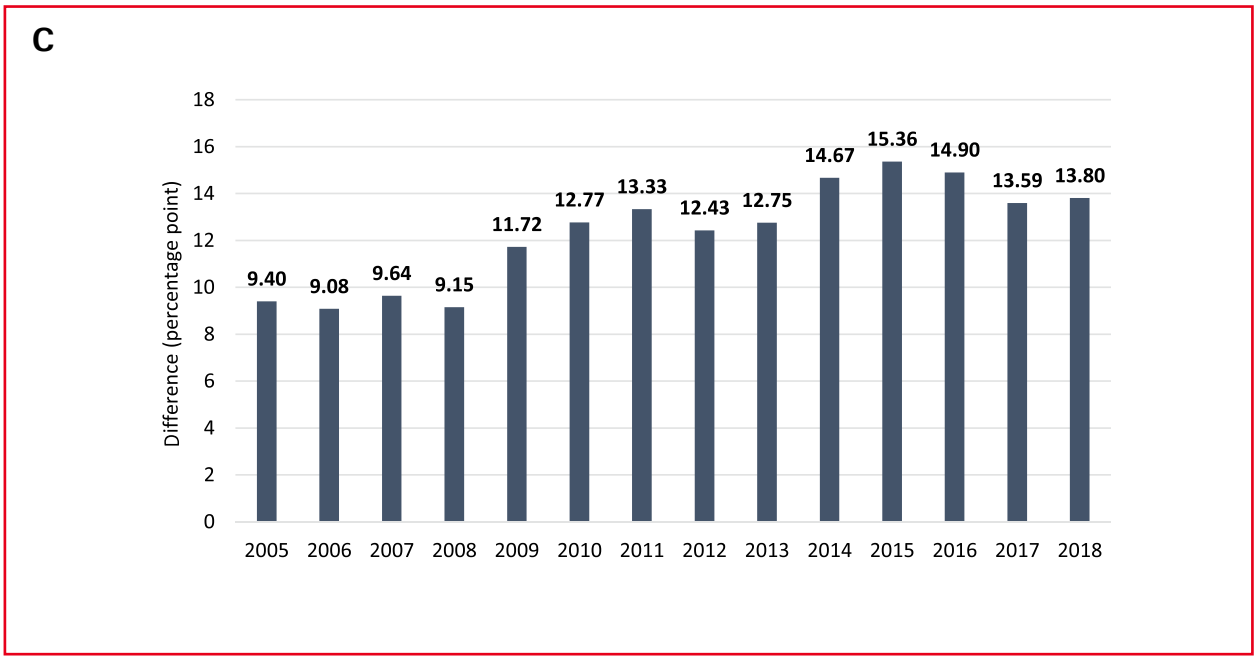


Figure 2. Sex structure (%) of Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018): **(A)** first-time donors (FTD), **(B)** repeat donors (RD) and **(C)** difference in the frequency of females among first-time donors (FTD) and repeat donors (RD)

in the analysed period (2005 vs. 2018 $p < 0.05$) (Fig. 3). The largest increment was recorded in the 41–50 age group — by 13.05 p.p., from 12.68% in 2005 to 25.73% in 2018 ($p < 0.05$). The smallest reported increment, by 3.72 p.p. from 12.62% in 2011 up to 16.34% in 2018 ($p < 0.05$) referred to the oldest donors (> 60 years). In the other age groups, significant increase ($p < 0.05$) was always observed in: the youngest age group (≤ 20) by 10.53 p.p. (from 2005 to 2017), 31–40 age group by 7.95 p.p. (from 2005 to 2015), 51–60 age group by 7.91 p.p. (od 2005 to 2018) and 21–30 age group by 7.9 p.p. (from 2005 to 2015). The increase in the percentage of women donors continued throughout the observation period for 41–50 age group ($R = +1$; $p < 0.05$), and for 51–60 age group (2005–2018: $R = +0.96$; $p < 0.05$) with a temporary reversal of trend in 2010 (2005–2008: $R = +1$; 2008–2010: $R = -1$; 2010–2018: $R = +1$; $p < 0.05$). An increase in the percentage of women donors was observed in the youngest group of donors (≤ 20) until 2017 ($R = +0.99$; $p < 0.05$), while for donors of the next two age groups, the trend was evident until 2015 (21–30: $R = +1$; 31–40: $R = +0.97$; $p < 0.05$), with a temporary decrease in the 31–40 age group in 2013. The percentage of women in the oldest group of blood donors was relatively stable and ranged from 12.62% in 2011 to 14.80% in 2017 ($R = 0.29$, $p > 0.05$).

Demographic changes; men vs. women by region

In individual Blood Transfusion Centers (BTCs) the reported percentage of men and women in the donor population varied. In BTC in Racibórz, 20.78% of blood donors eligible for donation were women and in Białystok — 32.18% (difference of 11.4 p.p.; $p < 0.05$). In all BTCs the percentage of men eligible for donation was higher than of women ($p < 0.05$) (Fig. 4).

Percentage of first-time and repeat donors in the population of donors eligible for donation (2005–2018)

Most Polish blood donors in the period 2005–2018 were repeat blood donors — 66.78%, vs. 33.22% (first-time donors). There is a noticeable increase in the percentage of repeat blood donors in the analysed period ($R = +0.97$; $p < 0.05$) (Fig. 5). The lowest frequency of repeat blood donors was observed in 2007 — 55.39% [55.26–55.53%], and in the later years this parameter continuously increased until 2016 up to 75.22% [75.11–75.32%]. The largest difference in the percentage of repeat blood donors among blood

Tabela 2. Frequency (%) of first-time (FTD) and repeat (RD) donors by age groups among Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) (cumulative data)

Age group	Numer of donors			Donor frequency (%)	
	All	Men	Women	Men [95% CI]	Women [95% CI]
≤ 20	1 831 885	1 172 267	659 618	63.99 [63.92–64.06]	36.01 [35.94–36.08]
21–30	3 015 039	849 769	2 165 270	28.18 [28.13–28.24]	71.82 [71.76–71.87]
31–40	1 793 221	387 053	1 406 168	21.58 [21.52–21.64]	78.42 [78.36–78.48]
41–50	987 250	194 744	792 506	19.73 [19.65–19.80]	80.27 [80.20–80.35]
51–60	424 922	79 741	345 181	18.77 [18.65–18.88]	81.23 [81.12–81.35]
> 60	40 255	5162	35 093	12.82 [12.50–13.15]	87.18 [86.85–87.50]

CI — *confidence interval*

donors (19.83 p.p.) was observed between 2007 and 2016 ($p < 0.05$).

An upward trend in the percentage of repeat donors in the population of donors eligible for donation was reported for both women ($R = +0.99$, $p < 0.05$) and men ($R = +0.97$, $p < 0.05$) (Fig. 6). The percentage of repeat donors increased by 21.15 p.p. for women — from 44.76% [44.44–45.08%] in 2005 to 65.91% [65.68–66.13%] in 2018 and for men — by 20.6 p.p. from 58.49% [58.33–58.64%] in 2007 to 79.09% [78.97–79.20%] in 2016. The change was statistically significant for both groups ($p < 0.05$).

There were always more first-time blood donors among women than among men, the difference ranged from 12.33 p.p. (52.36% vs. 40.03%) to 15.02 p.p. (46.62% vs. 31.60%), depending on the year of analysis (always $p < 0.05$).

First-time and repeat blood donors in the individual age groups of Polish donors (2005–2018)

With the exception of the youngest group (≤ 20), in all age groups repeat blood donors were the majority. The percentage of repeat donors successively increased in the subsequent age groups from 36% in the youngest (≤ 20 years) to 87% in the oldest (> 60 years), ($R = +0.94$; $p < 0.05$). The largest difference in the number of repeat donors was observed between the ≤ 20 and 21–30 age groups (35.81 p.p.; $p < 0.05$). The reported increase in the percentage of repeat blood donors in the subsequent age groups was by several percent ($p < 0.05$) (Table 2).

Change in the percentage of first-time and repeat blood donors in the individual age groups of Polish blood donors (2005–2018)

Higher percentage of repeat blood donors in the individual years of the analysed period, was recorded for all age groups, although the dynamics of change differed. The largest increment was recorded in the oldest age group (> 60) by 28 p.p. (from 66.18% in 2005 to 94.18% in 2017), in the 21–30 age group by 19.54 p.p. (from 61.23% in 2008 to 80.77% in 2015) and in the 51–60 age group by 19.01% — from 70.25% in 2005 to 89.26% in 2017 ($p < 0.05$).

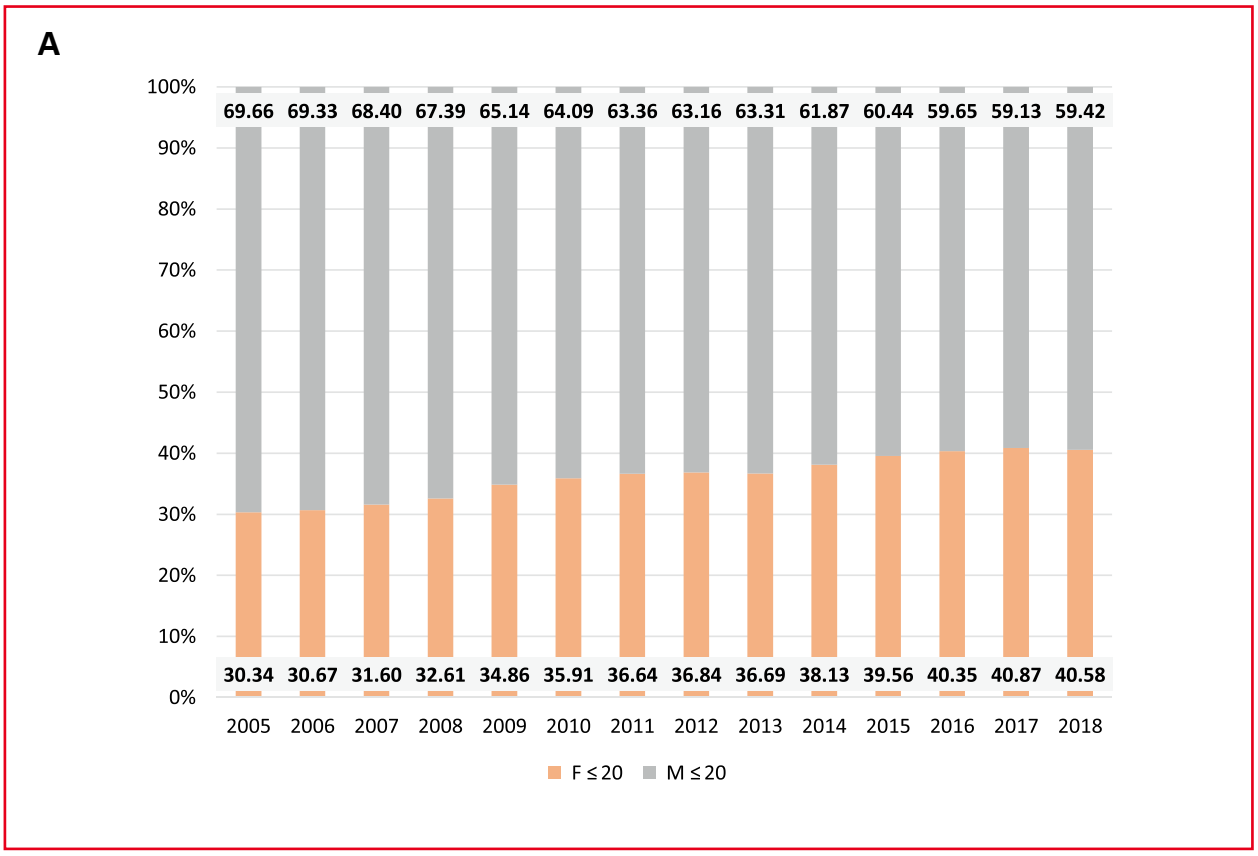
The smallest increment in the percentage of repeat blood donors was observed in the youngest age group — from 29.03% in 2005 to 40.36% in 2013, i.e. by 11.33 p.p. ($p < 0.05$). In the 41–50 age group, the percentage of repeat blood donors increased by 14.21 p.p. — from 72.14% in 2007 to 86.35% in 2016 ($p < 0.05$); in the 31–40 age group by 15.75 p.p. — from 69.07% in 2005 to 84.82% in 2016 ($p < 0.05$). In most age groups, the greatest changes were observed for the years 2009–2014 (Fig. 7).

The proportion of first-time donors to repeat donors varied between BTCs. During the 14-year period, the proportion was the largest in BTC of Racibórz and Białystok (76.5% and 75.93% respectively), and the lowest in BTC of the Ministry of Internal Affairs and Administration (50.45%) and the Military BTC (45.54 %) (Fig. 8).

Analysis of donor age

Figure 9 presents the structure of donor age. According to the data referring to the analysed period, most Polish blood donors were young — most of them (60%) under the age of 31.

In the period 2005–2018, differences were observed between first-time and repeat blood donors as regards age structure. First-time donors were younger than repeat donors ($p < 0.05$); 75.20% of first-time donors belonged to the two youngest age groups (≤ 30), while only 52.28% of repeat donors were ≤ 30 years old ($p < 0.05$). In the 31–50 age group there were 21.64% of first-time blood donors and more than 40.69% of repeat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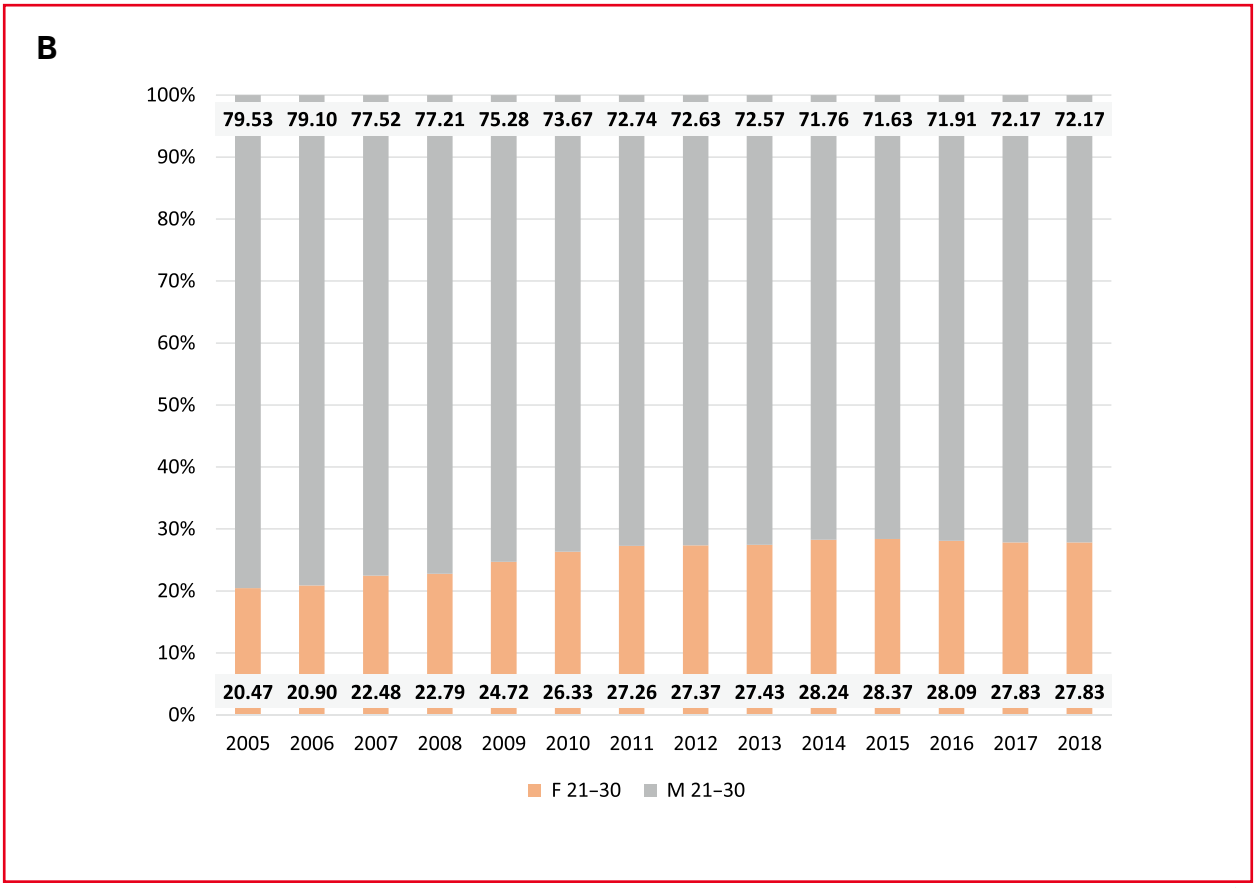
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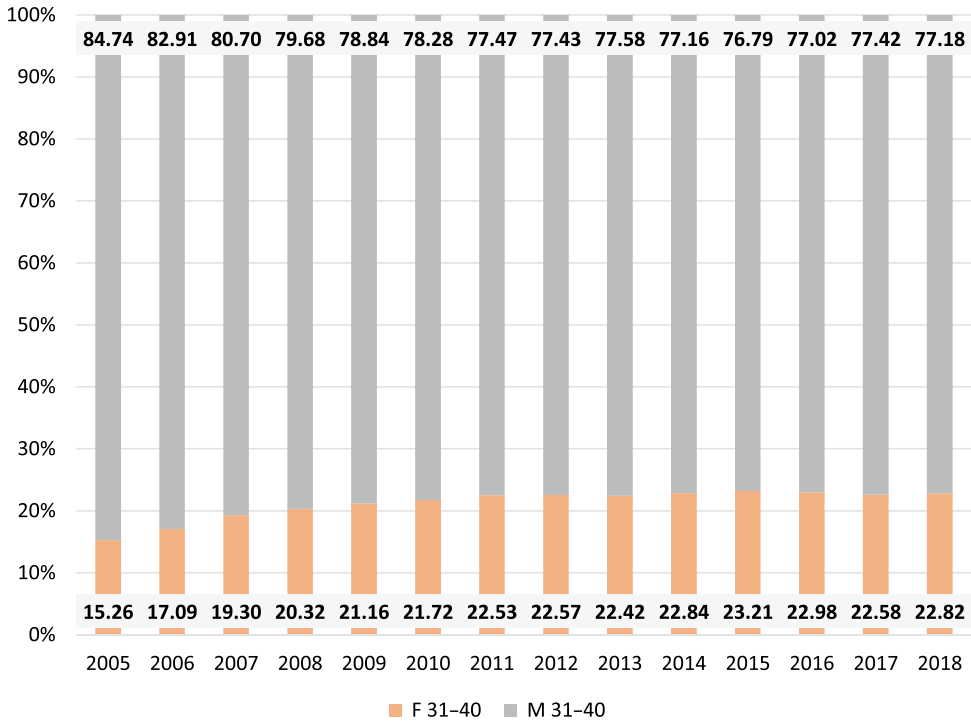
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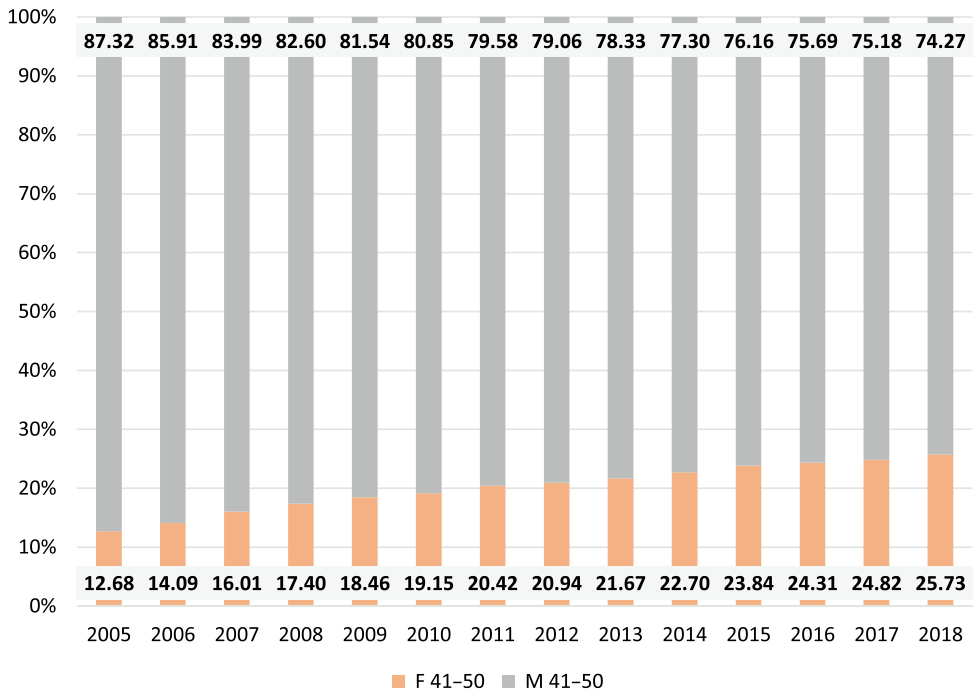
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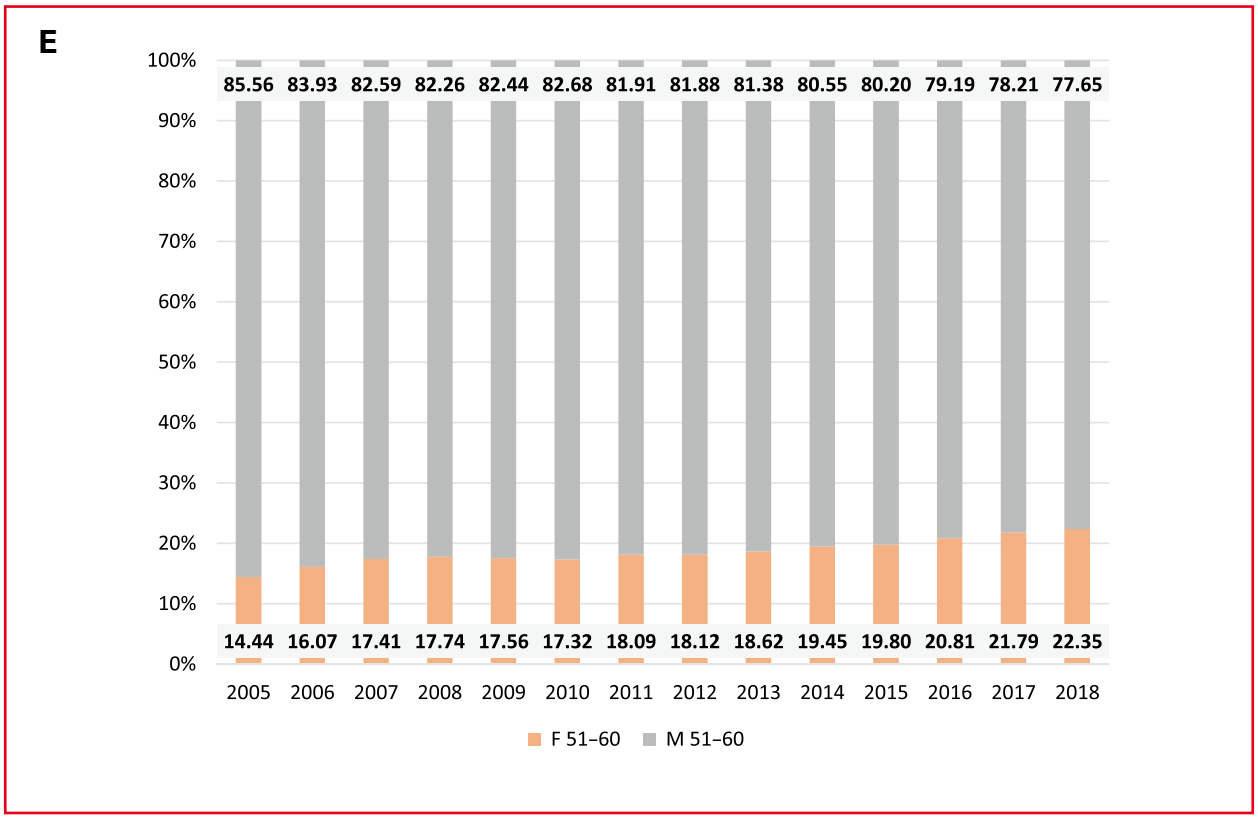


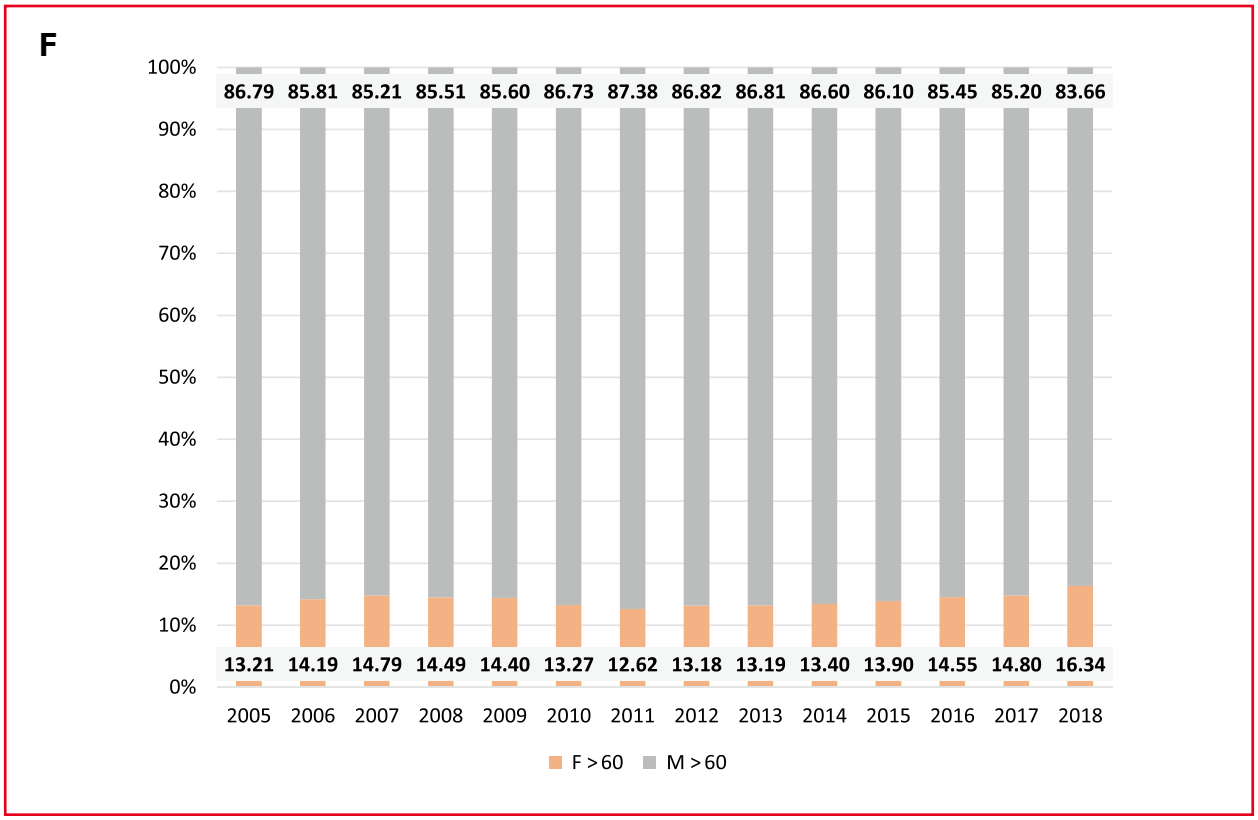


Figure 3. Change (%) in sex structure (F — females and M — males) in the following age groups: **(A)** ≤ 20, **(B)** 21–30, **(C)** 31–40, **(D)** 41–50, **(E)** 51–60, **(F)** > 60 of Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018)

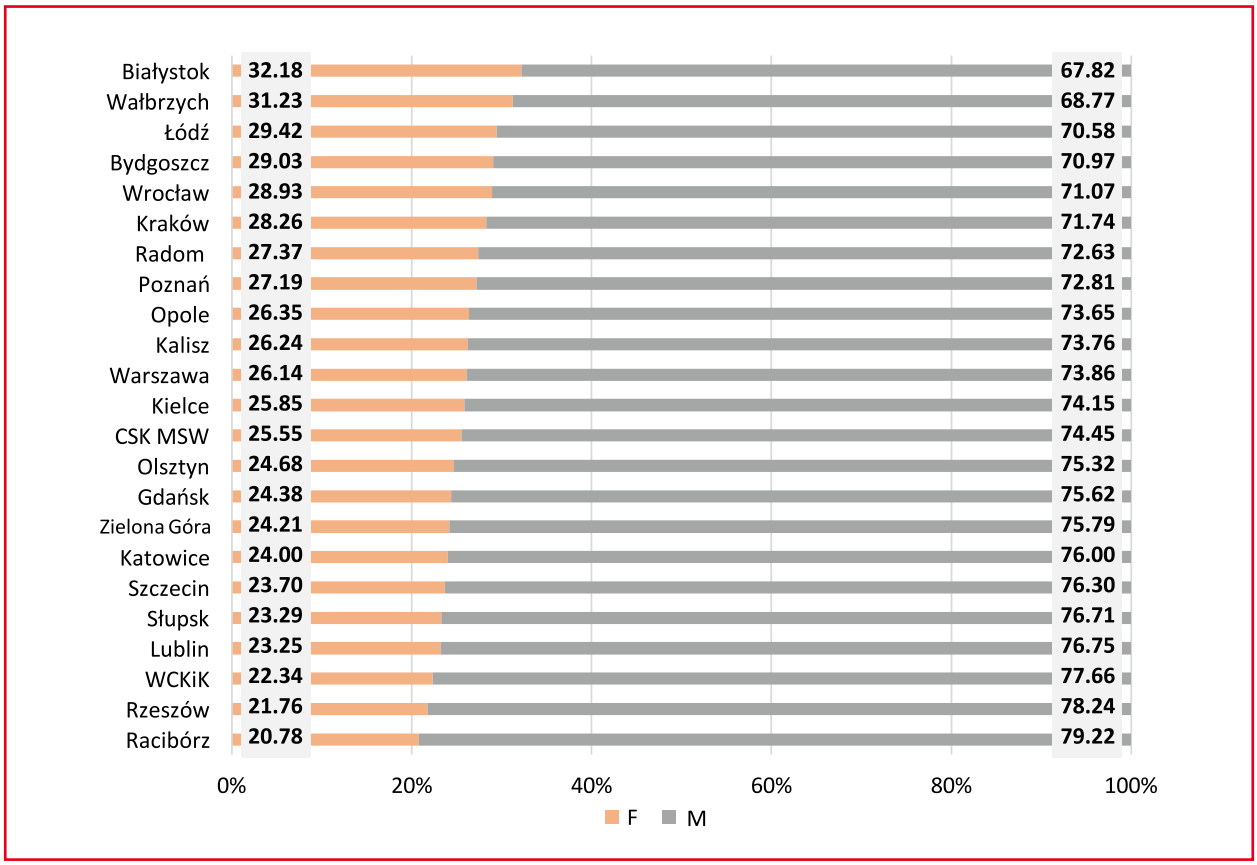


Figure 4. Frequency (%) of females (F) and males (M) among Polish blood donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) in individual BTCs (cumulative data)

blood donors ($p < 0.05$). Only 3.16% of first-time donors and 7.04% of repeat donors were > 50 years old (Fig. 10A).

There were also differences in the age structure of men and women donors (Fig. 10B). In the total donor population, women were younger than men; 68% of women and only 57% of men were from the two youngest age groups ($p < 0.05$). The percentage of women ≤ 20 was 11.6 p.p. higher than that of the youngest men ($p < 0.05$), while the percentage of men and women donors in the 21–30 age group was similar (36.90% vs. 37.38%) ($p < 0.05$). Among donors aged > 40, there were fewer women (13.55%) than men (19.50%) ($p < 0.05$).

In the 2005–2018 period, there occurred changes in the age structure of all donors, in the subpopulation of first-time and repeat donors, as well as in the number of men and women donors. The data presented in Figures 11 A–E demonstrate the "aging" trend in the whole population of Polish blood donors and its subpopulations, particularly in the last years of the period.

Figure 11A presents the changes in the percentage of individual age groups in the whole population of donors for each year of the period under analysis. In the consecutive years, the percentage of donors from the 31–40, 41–50 and > 60 age groups increased from 17.59% to 28.28%, 10.48% to 15.27% (since 2011) and 0.28% to 0.72% respectively. The greatest changes were recorded in the percentage of the age groups ≤ 20 (decrease from 23.45% to 16.19%) and 31–40 (increase from 17.59% to 28.28%). Alternatively, these two age groups, were the second and third most numerous. In the period 2005–2010, a decrease in the percentage of blood donors aged 21–30 ($p < 0.05$ for $R = -0.89$, changes by 1.93 p.p.) and 41–50 ($p < 0.05$ for $R = -1$; change by 3.43 p.p.) was observed and an increase of 2–3 p.p. in the 31–40 age group ($R = +1$; $p < 0.05$) and the youngest group ($R = +0.75$; $p = 0.052$). The years 2012–2018, witnessed an increase in 31–40 age group ($p < 0.05$ for $R = +1$ and a change of 6.78 p.p.) and the 41–50 age group ($p < 0.05$ for $R = +1$ and a change of 4.74 p.p.) with a simultaneous decrease in

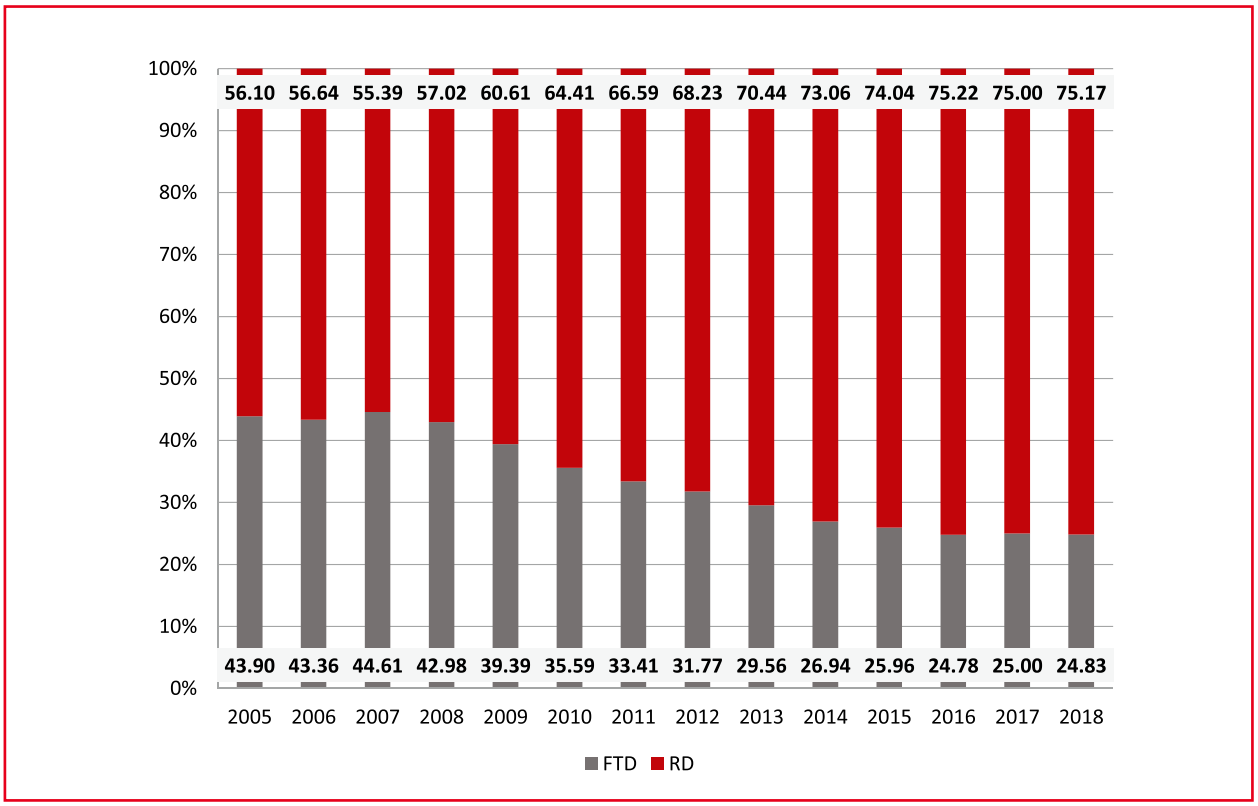


Figure 5. Frequency (%) of first-time donors (FTD) and repeat donors (RD) among Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018)

the percentage of the 21–30 age group ($p < 0.05$ for $R = -0.96$ and a change by 3.03 p.p.) and the youngest group ($p < 0.05$ for $R = 1$ and changes by 8.18 p.p.). During the 14 years of observation, the highest increase in the percentage of donors was recorded in the 31–40 age group (from 17.59% in 2005 to 28.28% in 2018), and the lowest in the > 60 age group (from 0.28% to 0.72%) (for both groups $p < 0.05$ and $R = +1$). The largest decrease was observed for the youngest age group — from 25.83% in 2010 to 16.19% in 2018.

In the group of first-time donors (Fig. 11B), every year of the period under analysis marked the highest participation of the youngest age group of donors (from 37.9% in 2005 to 48.8% in 2014, $p < 0.05$), the lowest of the oldest age group (from 0.15% in 2011 and 2017 to 0.23% in 2007, $p < 0.05$). The age structure in this subpopulation changed with the consecutive years. Between 2005 and 2011, there was a noticeable decrease in the percentage of blood donors aged 21–30 ($p < 0.05$ for $R = -1$; change by 7.8 p.p.), 41–50 ($p < 0.05$ for $R = -1$; change by 2.66 p.p.) and 51–60 ($p < 0.05$ for $R = -0.78$; change by 0.84 p.p.), while an increase was recorded in the group of donors aged 31–40 ($p < 0.05$ for $R = +0.85$ a change by 1.26 p.p.) and the youngest donors ($p < 0.05$ for $R = +1$ and a change by 10.1 p.p.). In the years 2012–2018, there was an increase in the percentage of donors aged 31–40 ($p < 0.05$ for $R = +0.89$; change by 3.25 p.p.) and 41–50 ($p < 0.05$ for $R = +0.89$; change by 2.63 p.p.). At the same time, a decrease in the number of donors aged 51–60 was reported ($p < 0.05$ for $R = -0.89$; change by 0.51 p.p.). In the youngest group of donors, statistically significant changes ($p < 0.05$ for a change by 5.95 p.p.) were observed with no significant trend ($R = -0.6$ and $p > 0.05$). The smallest — though statistically significant — fluctuations were recorded in the oldest group of donors ($p < 0.05$).

Unlike in the subpopulation of first time donors, for repeat blood donors, each year of the 2005–2018 period, marked the highest percentage of donors aged 21–30 (from 36.30% in 2018 to 41.61% in 2012 vs. 27.41% in 2015 to 37.15% in 2005, $p < 0.05$). Between 2005 and 2018, there was a regular increment in the percentage of 31–40 age group ($p < 0.05$ for $R = +1$ and changes by 10.14 p.p.). In the other age groups, no regular increase or decrease was observed. In the period 2005–2010, the percentage of the

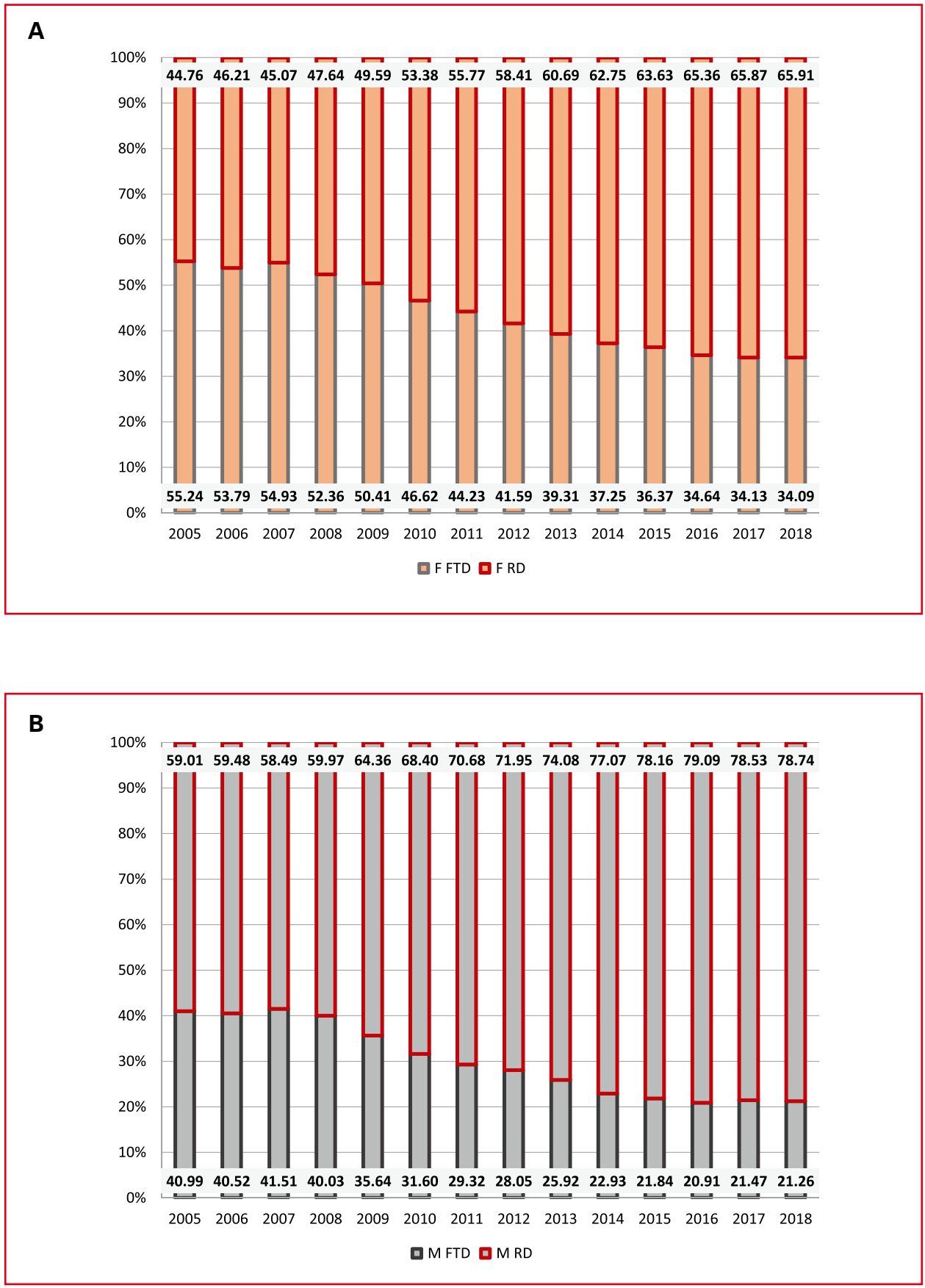
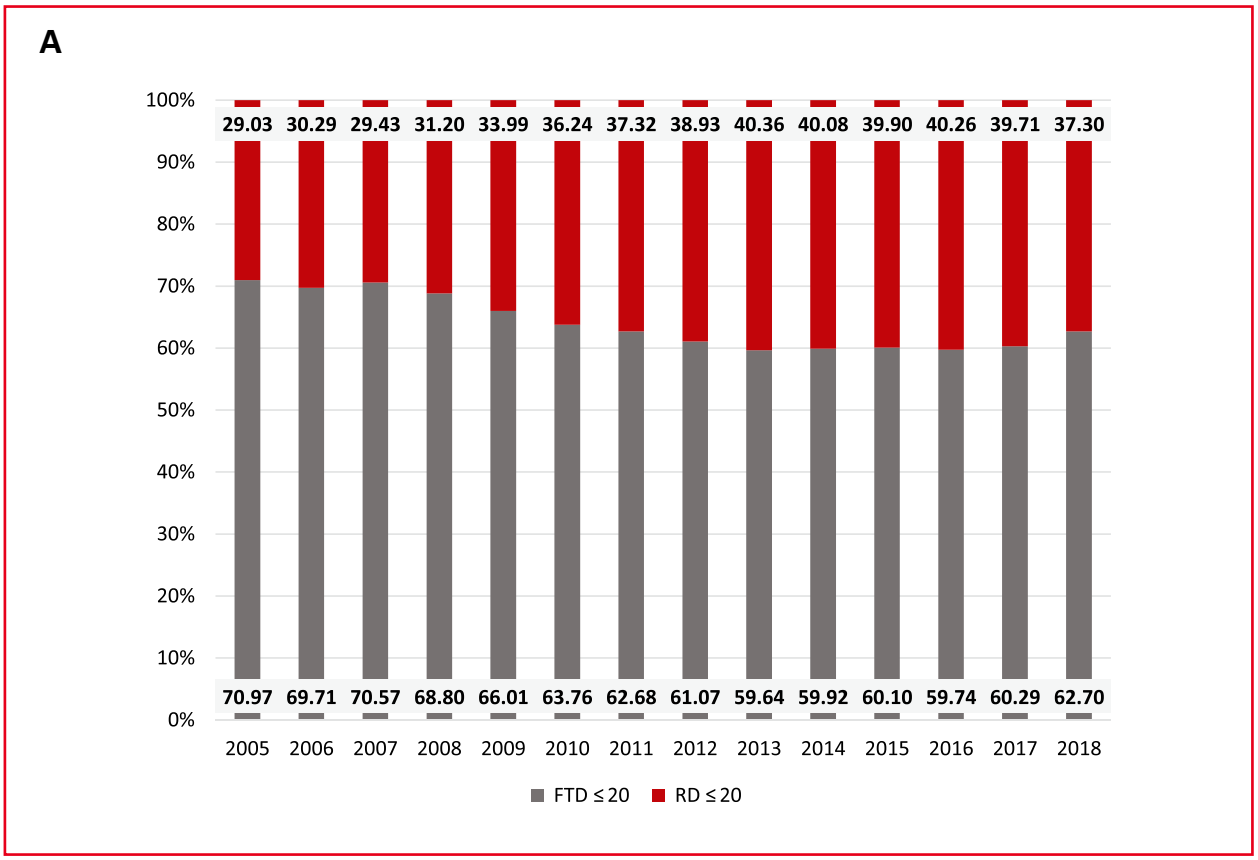


Figure 6. Frequency (%) of first-time donors (FTD) and repeat donors (RD) among Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) among **(A)** females (F) and **(B)** males (M)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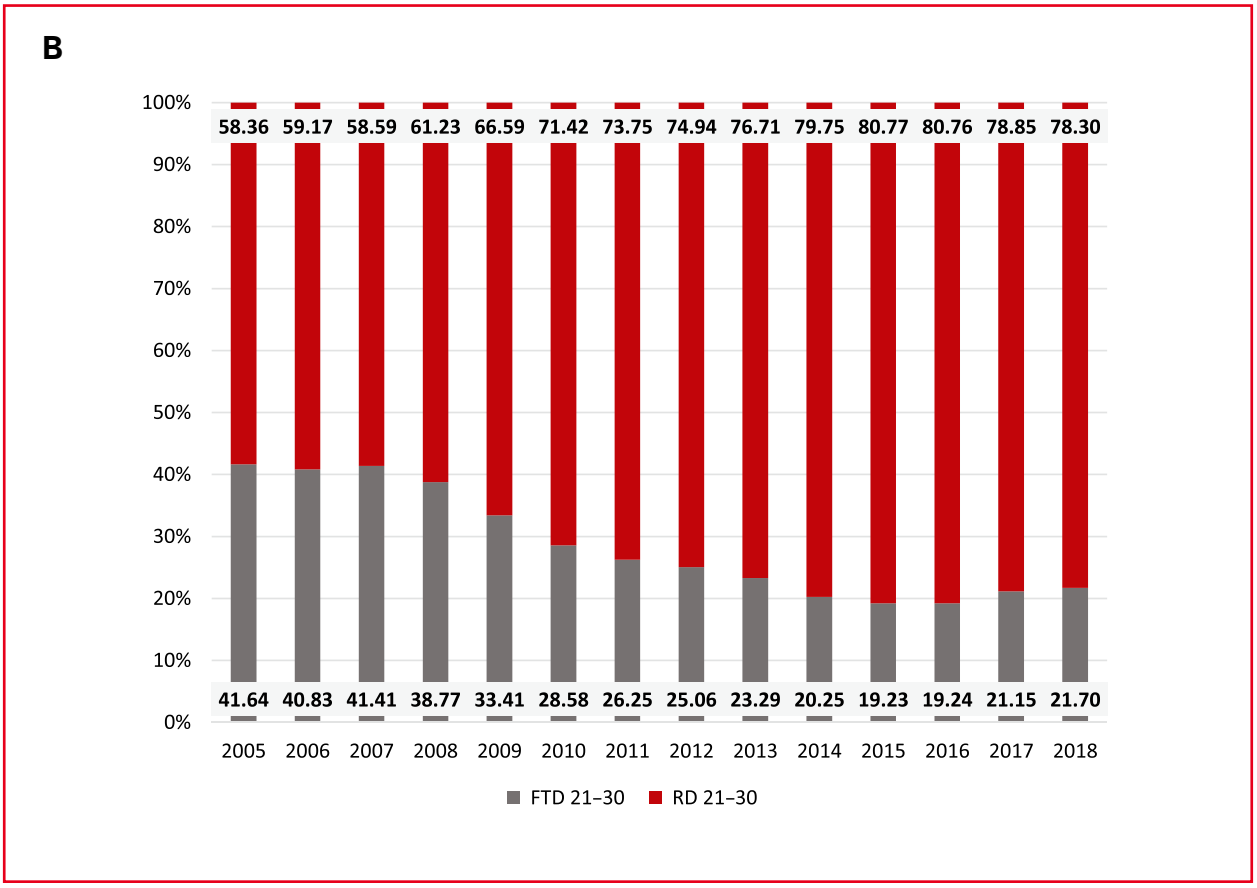
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
FTD ≤ 20
RD ≤ 20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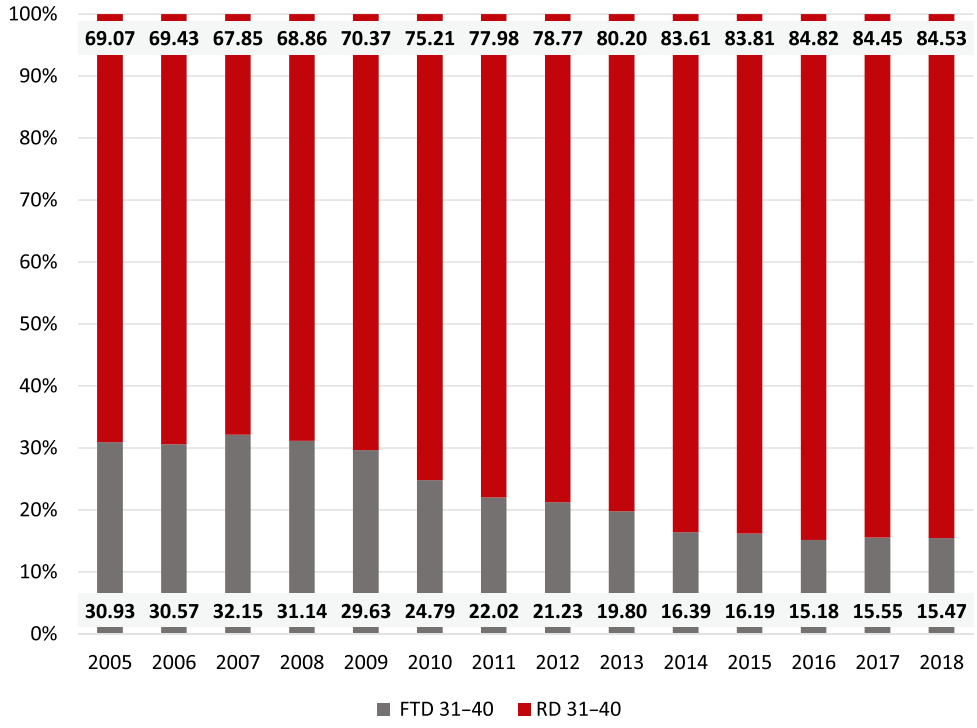
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
FTD 21–30
RD 21–30

C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FTD 31–40
RD 31–40

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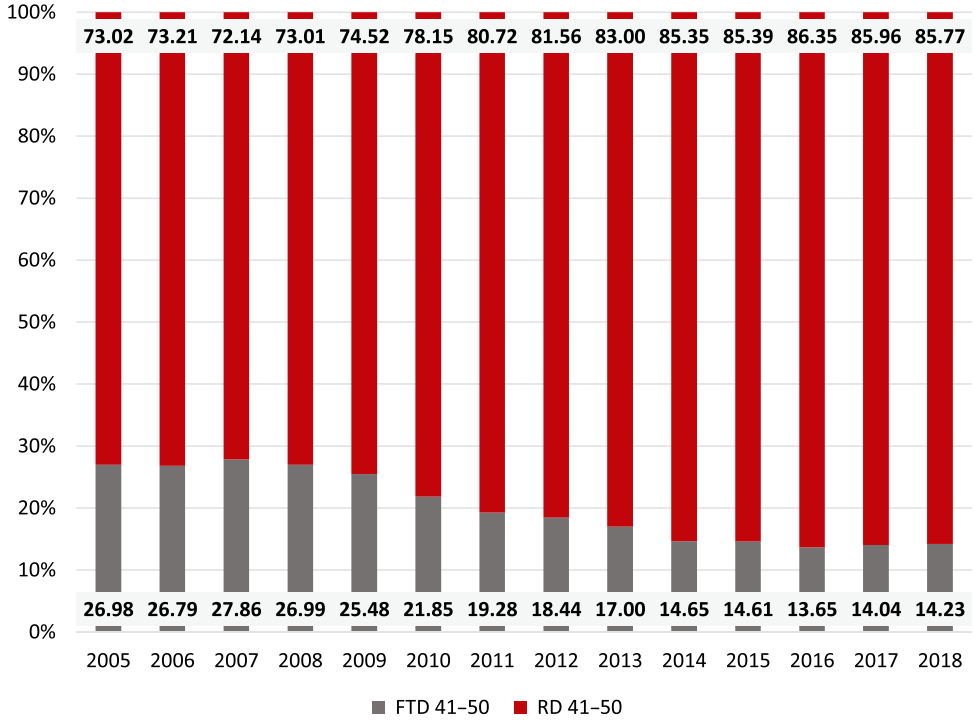
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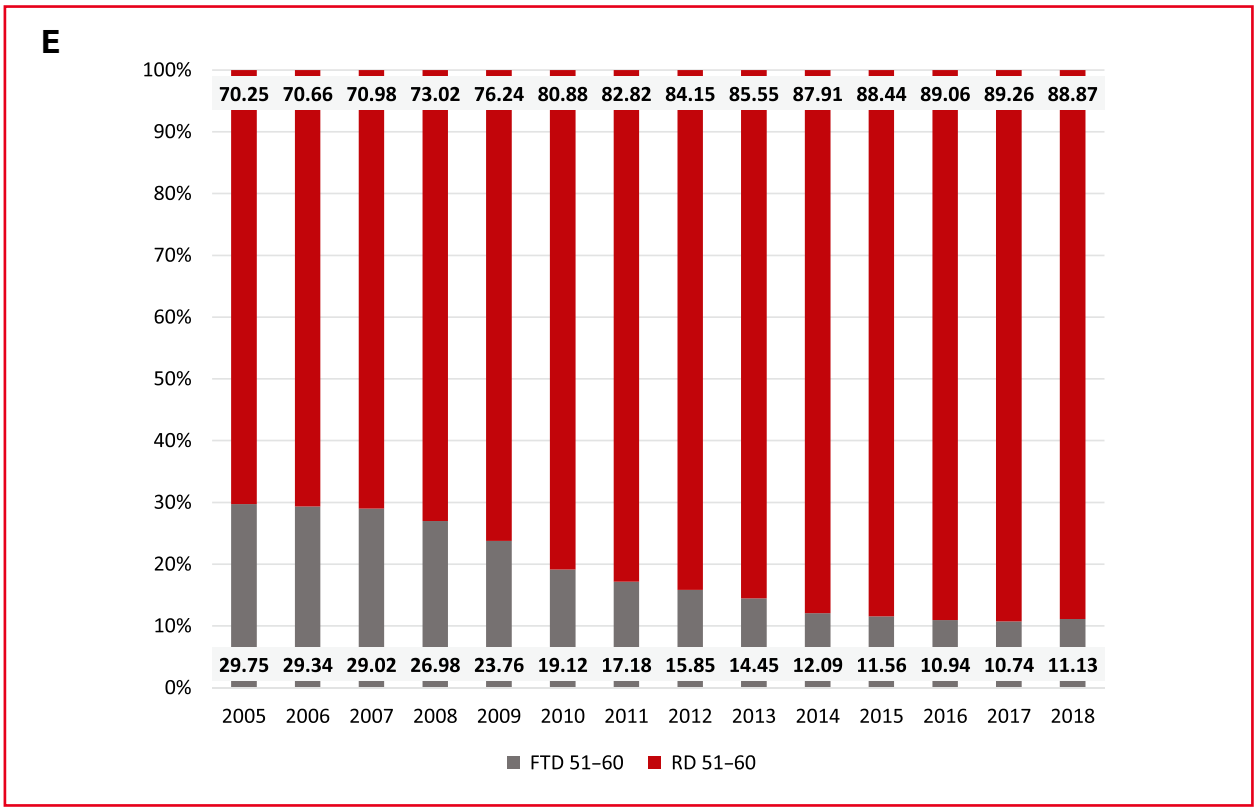
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
FTD 41–50
RD 41–50



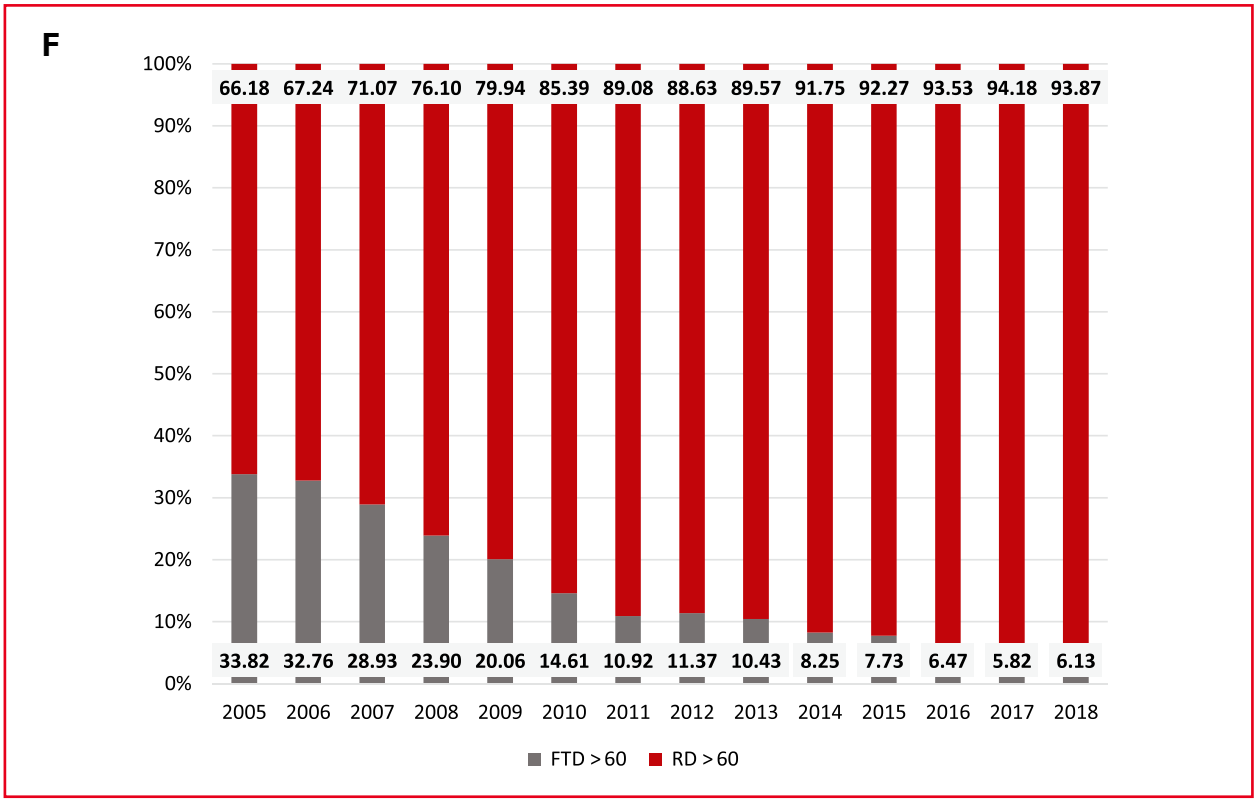


Figure 7. Frequency (%) of first-time (FTD) and repeat (RD) Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) by age groups: **(A)** ≤ 20, **(B)** 21–30, **(C)** 31–40, **(D)** 41–50, **(E)** 51–60, **(F)** > 60

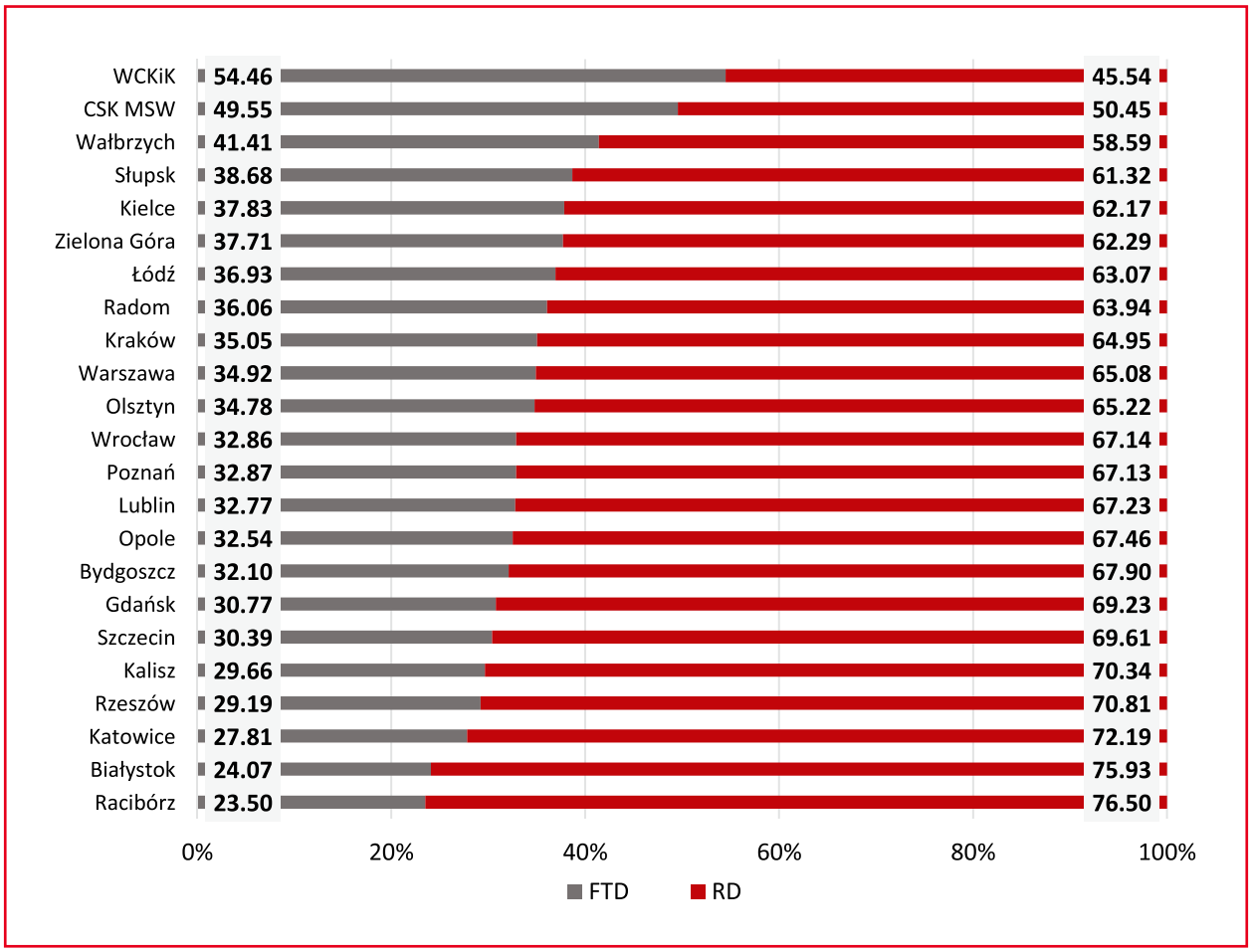


Figure 8. Frequency (%) of first-time (FTD) and repeat (RD) donors among Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) — analysis by regions

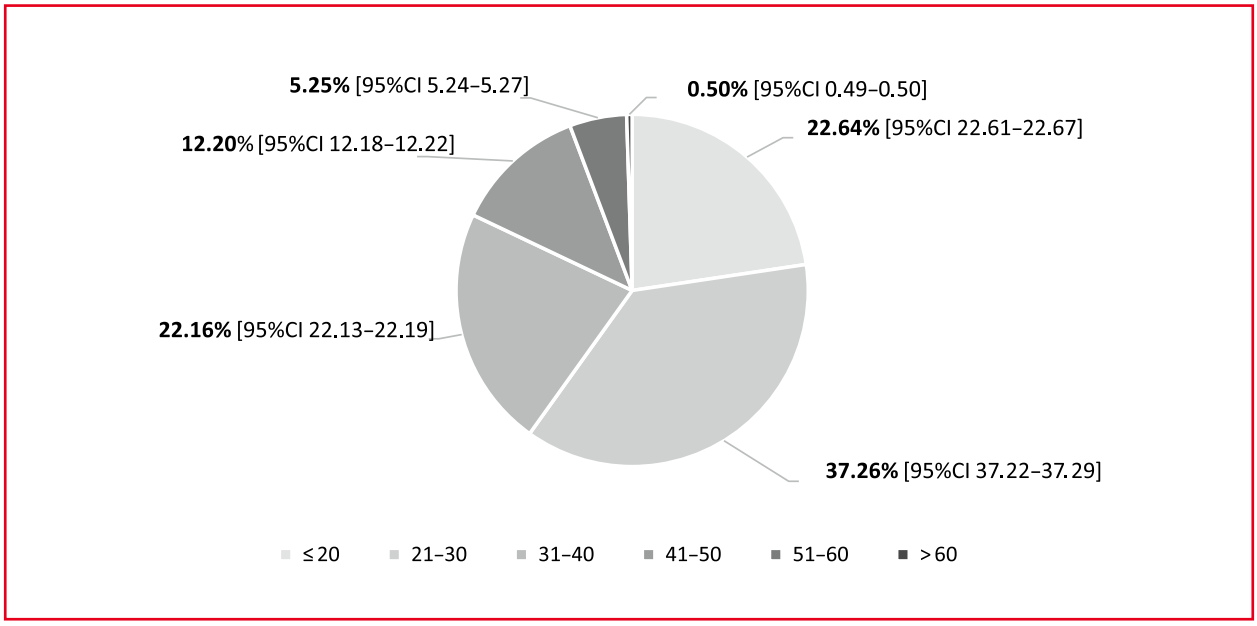


Figure 9. Frequency (%) of age groups in the population of Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) (cumulative data); CI — confidence interval

youngest donors increased by 2–3 p.p. ($R = +1$; $p < 0.05$). At that time, a decrease was reported in the percentage of donors aged 41–50 ($p < 0.05$ for $R = -1$ and a decrease by 5.42 p.p.). After 2010, a reverse of trend was observed in the 41–50, 21–30 and ≤ 20 age groups: the percentage of the two youngest age groups decreased: ≤ 20 ($p < 0.05$ for $R = -1$; decrease by 6.3 p.p.) and 21–30 ($p < 0.05$ for $R = -0.9$; decrease by 5.3 p.p.), while an increase was reported for the 41–50 age group ($p < 0.05$ for $R = +0.9$; an increase of 4.84 p.p.). In the years 2005–2018, the changes that occurred in the two oldest age groups — 51–60 and > 60 — were the smallest, though significant ($R = -0.87$; $p < 0.05$ and $R = +1$; $p < 0.05$) respectively (Fig. 11C).

Regardles of the observation year, in men and women donors the percentage of the 21–30 age group was the highest (from 35% in 2018 to 39% in 2005). In the years 2005–2018, a decrease in the percentage of men was recorded in this age group ($p < 0.05$; $R = -0.87$), while for women the changes were insignificant ($R = -0.4$; $p > 0.05$). In the period 2005–2018, a downward trend was observed for the youngest donor group — for both for men and women donors ($p < 0.05$ for $R = -0.75$ and $p < 0.05$ for $R = -0.89$ respectively). The tendency was even more evident after 2010 ($R = -1$; $p < 0.05$ for both men and women). During each year of the observation period, the number of women donors was higher in the youngest age group than in the 31–40 age group, while for men donors this was true only until the year 2011. The percentage of 31–40-year-old blood donors systematically increased throughout the observation period, both among both men and women — by 11.51 p.p. ($p < 0.05$ for 2005 vs. 2018) and 10.05 p.p. ($p < 0.05$ for 2005 vs. 2018) respectively. The percentage of donors in the 41–50 age group decreased until 2010; for women (from 8.91% in 2006 to 7.75% in 2010) and until 2012 for men (from 15.55% in 2005 to 11.47% in 2012), then steadily increased until 2018 — to 14.12% for women and 15.71% for men. An upward trend was reported for the oldest age group of donors (both men and women) ($p< 0.05$ for $R = +1$ in men and $p < 0.05$ for $R = +0.98$ in women). In the > 60 age group, an increase in the number was reported for men ($p < 0.05$ for a change of 0.53 p.p. from 0.3% to 0.83%) and for women ($p < 0.05$ for a change of 0.24 p.p. from 0.18% to 0.42%) (Fig. 11D–E).

In the period 2005–2018, the distribution of age groups in individual BTCs was similar. With the exception of BTC in Wałbrzych and the BTC of the Ministry of Internal Affairs and Administration, in all BTCs most donors (> 50%) were ≤ 30 years old and the largest percentage of donors (31.69–44.51%) were 21–30 years old. In BTC in Radom, the highest number of blood donors, i.e. 33.92%, was ≤ 20 years old, and the second largest age group were 21–30 year olds — 29.21% ($p < 0.05$). In the BTC of the Ministry of Internal Affairs and Administration and in BTC in Wałbrzych, the percentage of blood donors in the 21–30 and 31–40 age groups was similar (29.62% and 30.13%, $p > 0.05$ and 28.20% and 28.21% $p > 0.05$ respectively). In 13/23 BTCs, the second most frequently represented age group of donors was the ≤ 20 age group (from 22.88% in Military BTC to 28.52% in Słupsk). In the remaining 7 BTCs, it was the 31–40 age group (from 22.13% in Szczecin to 25.51% in Katowice). The percentage of blood donors in the 41–50 age group ranged from 8.9% to 18.9% ($p < 0.05$), and for 51–60, from 3.8% to 8.8% in the Military BTC and BTC of the Ministry of Internal Affairs and Administration, respectively ($p < 0.05$). The lowest percentage was recorded for the eldest donors; the highest number of the eldest donors were recorded in the BTC of the Ministry of Internal Affairs and Administration (1.6%), and the lowest (0.28%) in BTC in Poznań ($p < 0.05$) (Fig. 12).

Discussion

Demographic analysis for the years 2005–2018 demonstrates that within the population of Polish donors eligible for donation there were more repeat blood donors (67%) than first-time donors, more men (74%) than women and more young people (60% aged 18–30) than older. However, over the period of the last 14 years significant changes have occurred: the percentage of women increased (Fig. 1), as did that of repeat blood donors (Fig. 5), and persons above 30 (Fig. 9). The up to date epidemiological analyses performed in the Polish BTS demonstrate significant differences between the frequency of infections in first-time donors vs. repeat donors, between men vs women donors, and between age groups. Therefore it seems that demographic changes may affect the frequency of detection of viral markers of infections in the population of blood donors [1, 9–11]. As in the USA and many European countries, also in Poland seropositive HBV, HCV and HIV infections were more often detected in first-time donors than in repeat donors [1, 3–5, 9–12]. According to WHO recommendations, the safety of transfusion

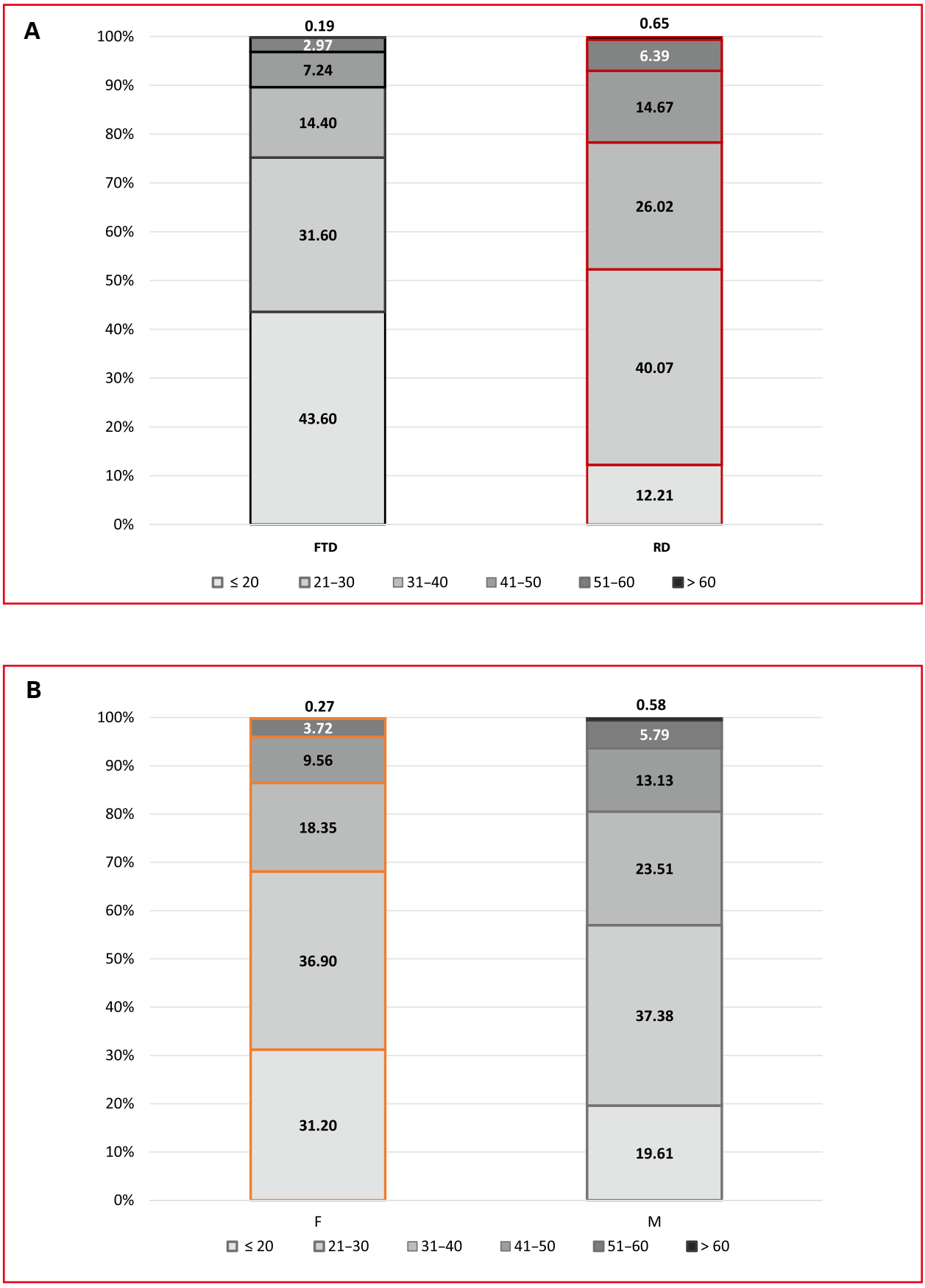
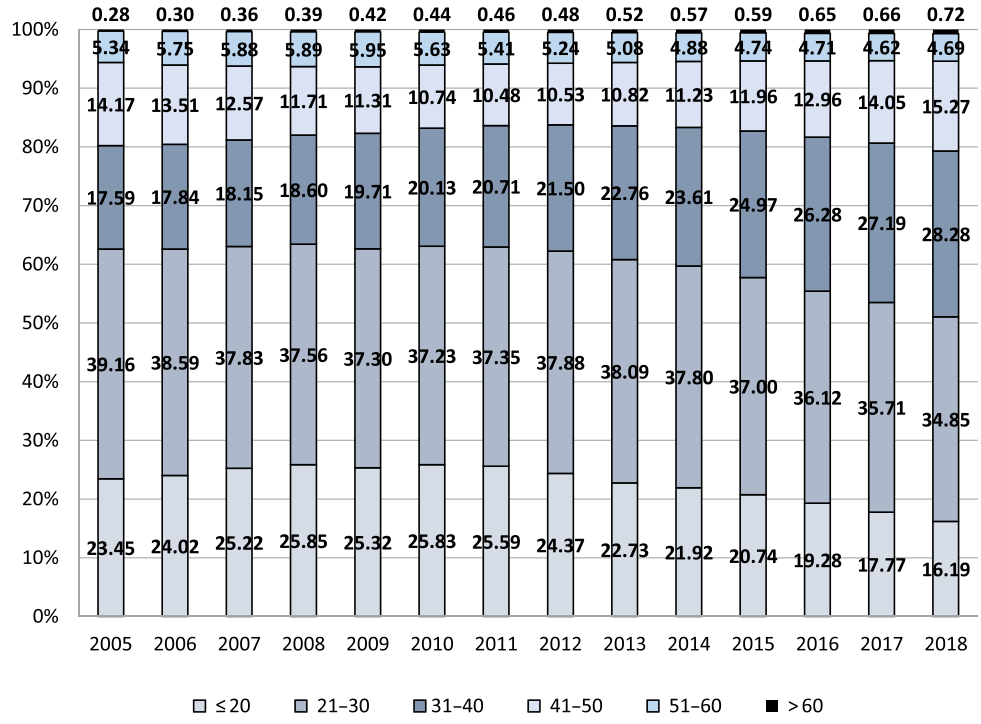
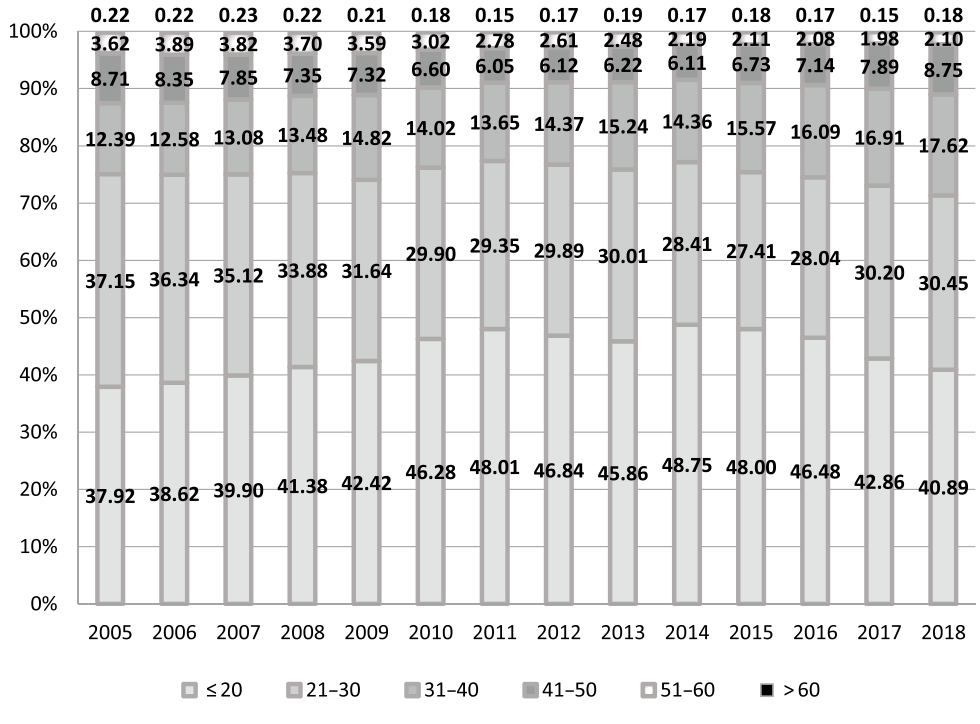


Figure 10. Age structure (%) of Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) among: **(A)** first-time (FTD) and repeat (RD) donors as well as **(B)** females (F) and males (M)

A


0.28 0.30 0.36 0.39 0.42 0.44 0.46 0.48 0.52 0.57 0.59 0.65 0.66 0.72
5.34 5.75 5.88 5.89 5.95 5.63 5.41 5.24 5.08 4.88 4.74 4.71 4.62 4.69
14.17 13.51 12.57 11.71 11.31 10.74 10.48 10.53 10.82 11.23 11.96 12.96 14.05 15.27
17.59 17.84 18.15 18.60 19.71 20.13 20.71 21.50 22.76 23.61 24.97 26.28 27.19 28.28
39.16 38.59 37.83 37.56 37.30 37.23 37.35 37.88 38.09 37.80 37.00 36.12 35.71 34.85
23.45 24.02 25.22 25.85 25.32 25.83 25.59 24.37 22.73 21.92 20.74 19.28 17.77 16.19
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
≤20 21–30 31–40 41–50 51–60 >60

B


0.22 0.22 0.23 0.22 0.21 0.18 0.15 0.17 0.19 0.17 0.18 0.17 0.15 0.18
3.62 3.89 3.82 3.70 3.59 3.02 2.78 2.61 2.48 2.19 2.11 2.08 1.98 2.10
8.71 8.35 7.85 7.35 7.32 6.60 6.05 6.12 6.22 6.11 6.73 7.14 7.89 8.75
12.39 12.58 13.08 13.48 14.82 14.02 13.65 14.37 15.24 14.36 15.57 16.09 16.91 17.62
37.15 36.34 35.12 33.88 31.64 29.90 29.35 29.89 30.01 28.41 27.41 28.04 30.20 30.45
37.92 38.62 39.90 41.38 42.42 46.28 48.01 46.84 45.86 48.75 48.00 46.48 42.86 40.89
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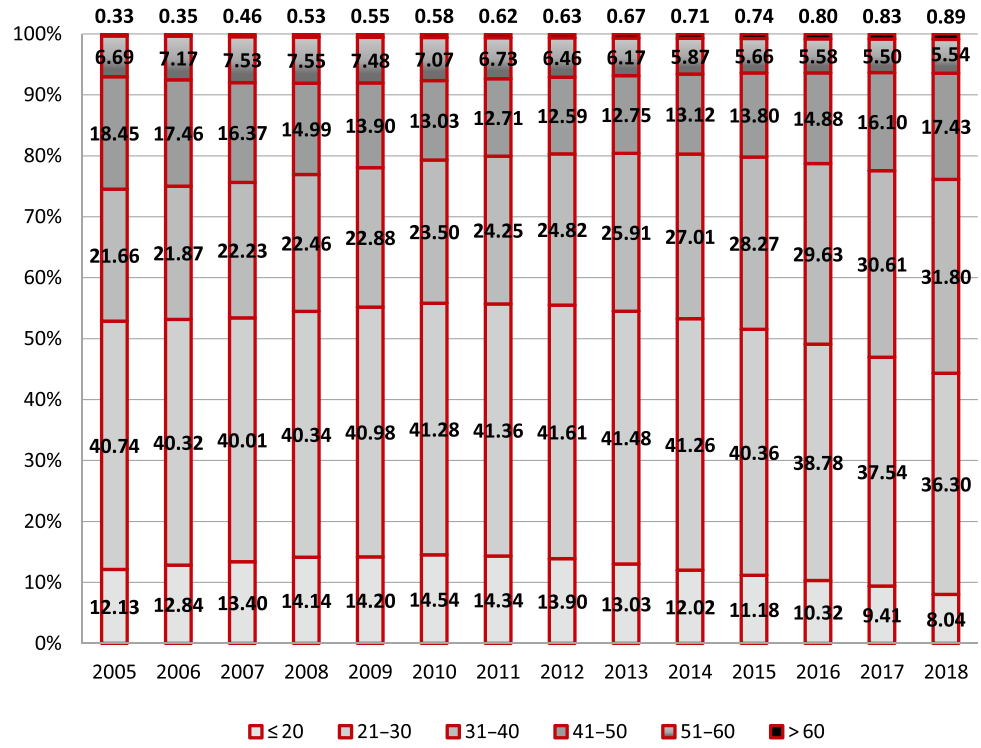
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
≤20 21–30 31–40 41–50 51–60 >60

C


0.33 0.35 0.46 0.53 0.55 0.58 0.62 0.63 0.67 0.71 0.74 0.80 0.83 0.89
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21.66 21.87 22.23 22.46 22.88 23.50 24.25 24.82 25.91 27.01 28.27 29.63 30.61 31.80
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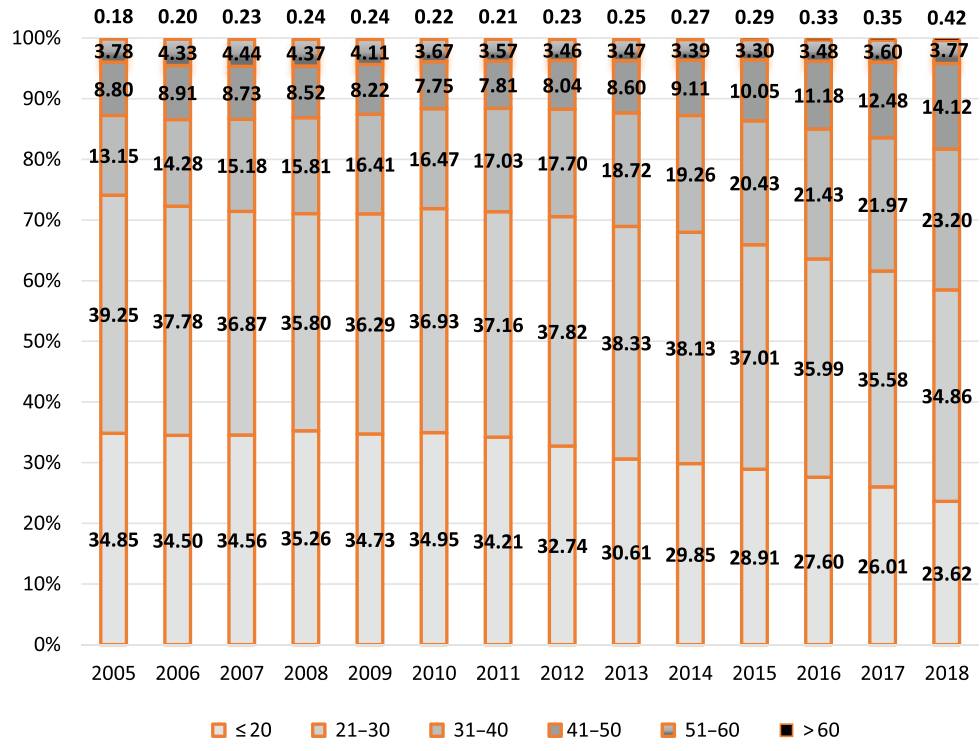
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8.80 8.91 8.73 8.52 8.22 7.75 7.81 8.04 8.60 9.11 10.05 11.18 12.48 14.12
13.15 14.28 15.18 15.81 16.41 16.47 17.03 17.70 18.72 19.26 20.43 21.43 21.97 23.20
39.25 37.78 36.87 35.80 36.29 36.93 37.16 37.82 38.33 38.13 37.01 35.99 35.58 34.86
34.85 34.50 34.56 35.26 34.73 34.95 34.21 32.74 30.61 29.85 28.91 27.60 26.01 23.62
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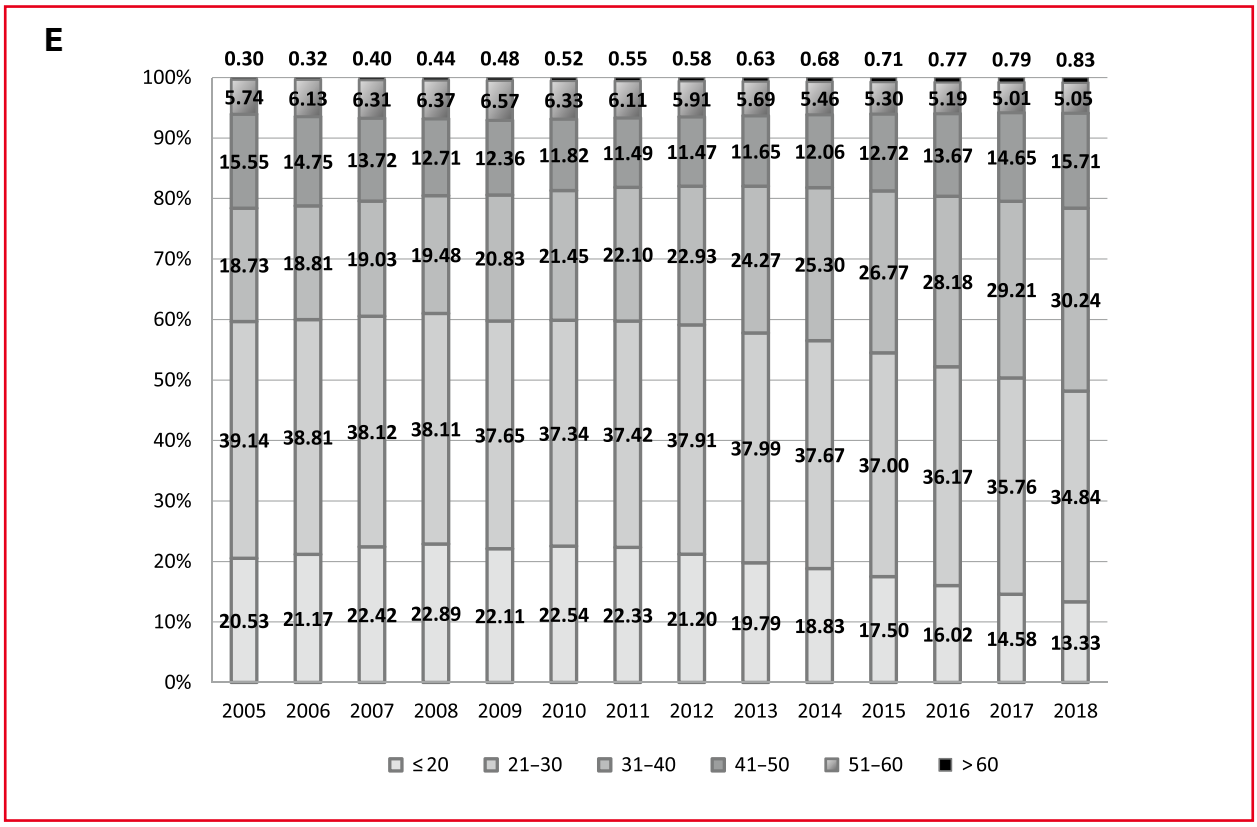

Figure 11. Change (%) in the age structure of Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) among: **(A)** all donors, **(B)** first-time donors (FTD), **(C)** repeat donors (RD), **(D)** females (F), **(E)** males (M)

is strengthened through implementation of effective measures to increase the number of repeat donors [2, 13–14]. Our own results referring to the period 2005–2018, confirm the increment of this subpopulation of blood donors by 19.8 p.p. Detailed multi-center analyses also demonstrate the relationship between the epidemiological status of the region and the demographics of blood donors [3–5]. So far, there have been no analyses of the impact of demographic changes on the frequency of transfusion-transmitted infections in the Polish BTS.

In 2005–2015, the average frequency of seropositive HBV and HIV infections was higher for men than for women donors (OR = 1.38 [1.32––1.45], $p < 0.05$ and OR = 3.7 [2.7–5.2], respectively, $p < 0.05$). The rate of seropositive infections was higher for first-time donors than repeat blood donors as regards HBV (OR = 90.9 [79.3–104.4]), HCV (OR = 22.5 [20.6–24.5]), and HIV (OR = 1.3 [1.1–1.6]) [9–11]. The downward trend in the percentage of men qualified for donation observed in this study may, at least partially, explain the improvement in the epidemiological situation in terms of HBV and HIV [10–11]. The observed lower frequency of infection for all three viruses may in turn be attributed to the decrease in the number of first-time donors.

It is worth mentioning that the relationship between demographics of blood donors and the epidemiology of transfusion-transmitted infections may result from preventive measures targeted at specific age groups. For instance, we believe that the decrease in the rate of seropositive HBV infection from 264.5/100,000 in 2005 to 53.1/100,000 in 2015 [11] resulted, mainly from implementation of mandatory vaccination against hepatitis B (EPI, *Expanded Program on Immunization*). In Poland, vaccines against HBV infection, have been administered since 1994 to professionals in everyday contact with human blood. Since 1996 vaccines became obligatory for all newborns and since 2000 to 2011 for person aged 14 [15]. As observed by Kopacz et al, the protective effect of HBV vaccine is demonstrated by the highest (21-fold) decrease in the frequency of HBV infections in the ≤ 20 age group of blood donors [11]. For this youngest group of donors hepatitis B vaccine was obligatorily at the

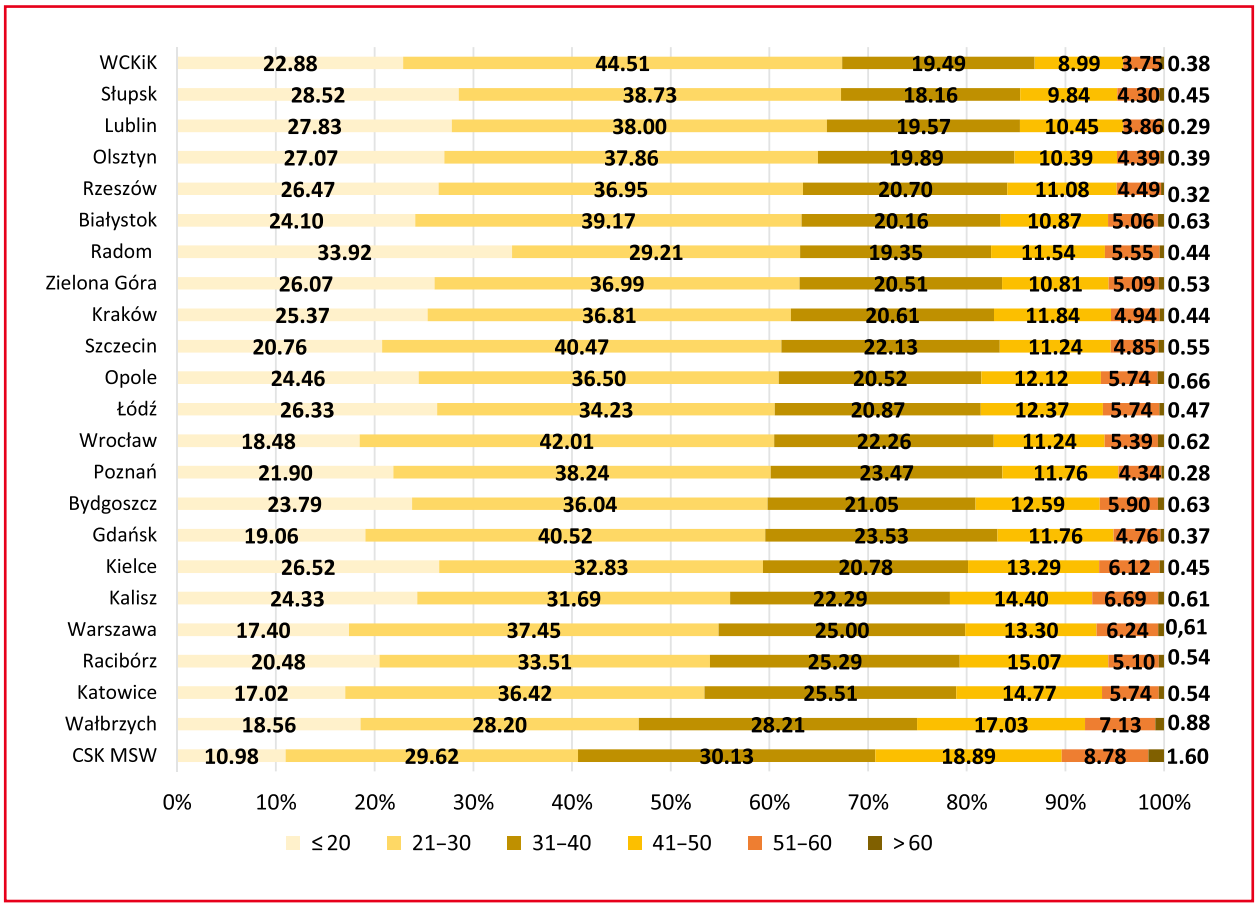

Figure 12. Age structure (%) of Polish donors found eligible for donation and subjected to screening for transfusion-transmitted infectious markers (2005–2018) in individual BTCs (cumulative data)

age of 14, and since 2014, at infancy. The hepatitis HBV vaccine significantly reduced the risk of HBV infection as confirmed by the decrease in the frequency of HBV infections in the general population of Poland (analogous period of observation) and this is particularly true for the youngest [16]. A similar reduction in the incidence rate and prevalence of HBV has been reported in other countries where HBV vaccination is obligatory [17]. All newborns have been vaccinated against hepatitis B as of 1996, it should therefore be expected that the younger the population of blood donors, the lower the frequency of HBsAg detection. Unfortunately, our own analyses as well as the study of A. Mikołowska et al. referring to the years 2012 and 2011 point to a downward trend for the frequency and the number of donors from the age groups that were obligatorily vaccinated with hepatitis B vaccine in infancy (0–1–6 months) [18, 19].

On the other hand, the increase in the frequency of seropositive HCV infections observed in Poland in the years 2005–2009 (from 146 to 367/100,000 blood donors), and then the decrease to 49/100,000 in 2015 [9] may have been caused by the initial increase in the percentage of the youngest age group of first-time blood donors (until 2010, HCV infections were most often detected in these donors), and then the decrease (Fig. 11B). The thesis may be supported by the fact that in the 2005–2018 period, there was no significant decrease in the incidence rate in the Polish population (the level of 5–7/100,000 is maintained), while the frequency of infections detected in people below 24 was observed to decrease [20–22]. The likely reason for the decrease in the frequency of HCV infections in blood donors seems to be the implementation (since 1980ies) of strategies effective for interrupting the transmission routes of HBV and HCV viruses (i.e. the use of disposable equipment, sterilization of medical devices, identification and treatment of patients with hepatitis C) as well as the observed decrease in the number of first-time blood donors.

In the years 2005–2015, Kubicka-Russel et al. demonstrated a statistically insignificant upward trend for the frequency of seropositive HIV infections [10]. This epidemiological tendency may be related to the increase in the percentage of blood donors aged 21–40, where the highest number of HIV infections were detected. In turn, no decrease in the incidence rate of HIV infections along with a decrease in the number of first-time blood donors may be explained by the fact that the largest decrease was recorded in the youngest age group, in which HIV infections are not as frequent as in people from the next two age groups.

The observed relationship between donor demographics and the frequency of infections in Polish BTS [1, 9–11] may help to encourage to donate the groups of blood donors with the lowest TT-risk. Keeping in mind that seropositive HBV and HIV infections are most common in first-time blood donors and in men, it seems that increasing the percentage of repeat blood donors and women would contribute to the reduction of infection frequency with these viruses in blood donors. The higher rate of HCV, HBV and HIV infection in first-time donors vs. repeat donors confirms that BTS should be based on repeat blood donation. Unlike HBV and HIV, HCV infections have been detected more frequently in women, so increasing the number of women-donors may not necessarily contribute to strengthening blood safety. Polish epidemiological analyses indicate that the highest infections rate were in age groups of donors: HCV ≤ 20, HIV 21–40, HBV ≤ 20 until 2014; from 2015, the rate of HBV infection was the lowest in the ≤ 20 age group. The highest rates of HBV, HCV and HIV infection for individual age groups might suggest that the transfusion-transmission safety of donated blood could be strengthened by encouraging particular age groups to donate. It is however, very difficult to identify age groups that are "free" for all three viruses, therefore it is extremely important to ensure blood safety through: educating donors to avoid risky behaviour and exposure to infection, rigorous eligibility procedure as well as serological and molecular screening tests.

The data reported by The Chief Statistical Office (GUS) for the consecutive years of the 2010–2018 period shows a similar percentage of men (approximately 49.7%) and women (approximately 50.3%) in the Polish population of 18–65 (age of most blood donors). (Supplementary material Fig. 13). GUS data present the following distribution of 18–65 years old Polish population 25%, 65% and 10% in age groups 18–30, 31–60 and 61–65 age groups, respectively [23] (Supplementary material Fig. 14). When we compare the GUS statistical data with our own observations (74% men, 26% women, 60% donors ≤ 30; donors by age groups: from 37% in 21–30 age group to 0.5% in the > 60 age group, Fig. 9), it follows that the population of blood donors screened for infectious diseases is not representative for the general Polish population of 18–65 year olds. In her study A. Mikołowska reports that only about 3% of the general working-age population volunteered to donate blood in the period under analysis [21]. According to GUS, in the period 2010–2018, the percentage of Polish citizens aged > 60, 41–50 and

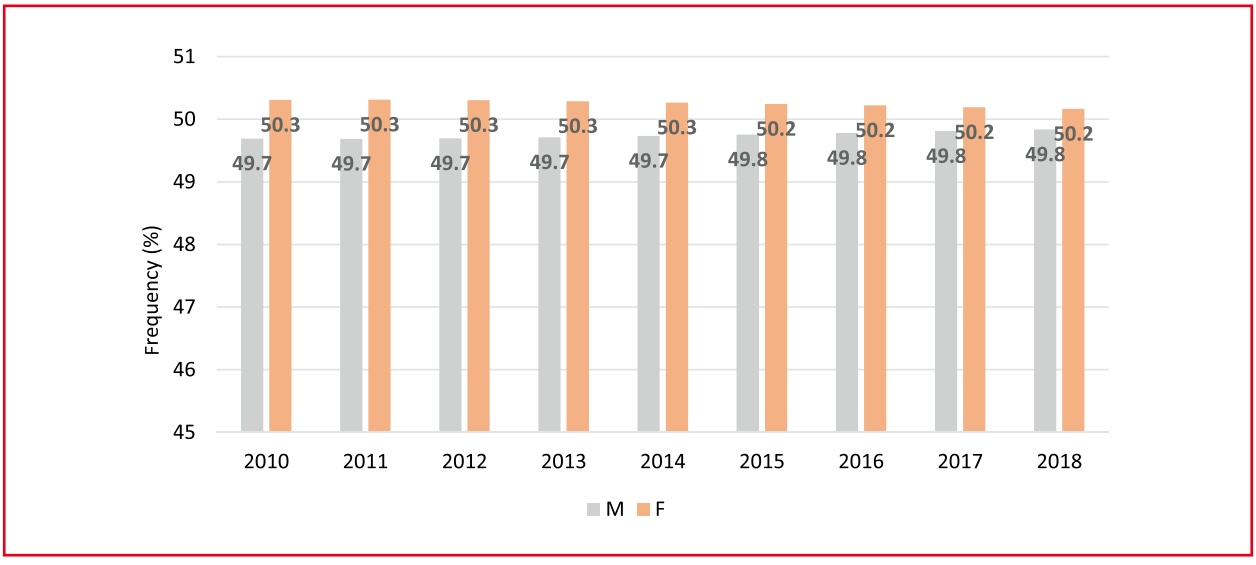

Figure 13. Frequency (%) of females (F) and males (M) in the Polish population aged 18–65 in the years 2010–2018 (RAPORTDEM_GUS [23])

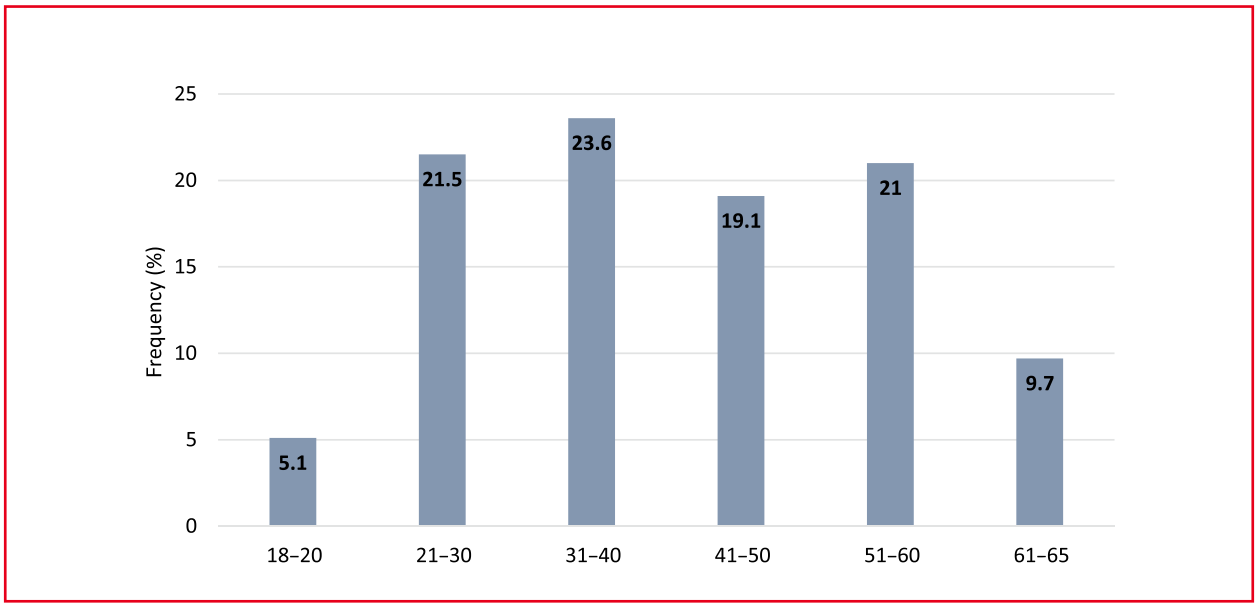

Figure 14. Frequency (%) of age groups in the Polish population aged 18–65 in the years 2010–2018 (RAPORTDEM_GUS [23])

31–40 years increased, while the percentage of citizens decreased in the age groups 51–60, 21–30 and 18–20. Trends in the general population are consistent with the trends observed in BTS (Fig. 11A), they do not however reflect the scale of change. For example, the increment in the percentage of the Polish population aged > 60 was estimated at 3 p.p., while that of donors in this age group at < 0.3 p.p. It may therefore seem that the trends observed for the general population may be predictive for the demographic trends in BTS. However, the trends observed in BTS can be translated to the general population with utmost caution taking into account the differences in the percentage of men and women as well as age groups between the general population and the population of blood donors screened for transfusion-transmitted infections.

Conclusions

The 2005–2018 period witnessed significant demographic changes in the population of Polish donors found eligible for donation of blood and blood components i.e. the number of women donors and repeat donors increased, with benefit for transfusion safety. The percentage of donors ≤ 30 oscillated around 61% until 2013, then decreased by about 2 p.p./year. This points to the aging trend in the population.

Conflict of interest: none declared

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