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Coronavirus Pandemic

Identification of risk factors that increase household transmission of COVID-19 in Afyonkarahisar, Turkey

Yiğit Şenol[1], Kadriye Avcı[2]

[1] *Afyonkarahisar Health Directorate, Afyonkarahisar, Turkey*
[2] *Department of Public Health, Faculty of Medicine, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey*

Abstract

Introduction: COVID-19 is the greatest pandemic of the 21st century. This cross-sectional study determined the factors that cause COVID-19 transmission in the household, increase in susceptibility of contacts, and increase in contagiousness of the primary case, and developed predictive calculations for determining secondary attack rate in the household.

Methodology: A total of 701 households with positive COVID-19 test cases, and 1813 adults living in these households, were studied from August 24-31, 2020 in Afyonkarahisar, Turkey. All the participants were interviewed by phone. The participants were divided into two groups: positives included those with positive Polymerase Chain Reaction (PCR) tests, negatives included those with a negative test and those who were without a PCR test. Descriptive statistics, Chi-square test, and multivariate logistic regression analysis were performed.

Results: The secondary attack rate was 31.5%. Being male, having an education level > 8 years, living in the city, low number of people living in the household, having a severe illness, non-compliance with isolation requirement, and nonadherence to wearing masks increased contagiousness. The factors that increased the sensitivity of the household were determined as being female, having an education level of over 8 years, and being obese.

Conclusions: The secondary attack rate (SAR) was higher in Turkey than in other countries and there was limited compliance with quarantine and isolation measures. Household transmission can be reduced by interventions such as masks, isolation, and quarantine. The transmission of COVID-19 in households can be reduced if preventive measures are taken in the early stages of infection.

Key words: Secondary; attack; rate; COVID-19.

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Introduction

Great success had been achieved in preventing infectious diseases until the 21st century. However, globalization, changes in microbial agents and human behaviour have resulted in emergence and re-emergence of infectious diseases [1]. Clearly, Coronavirus disease 2019 (COVID-19) has shown that infectious diseases still have significant potential to cause pandemics in the 21st century. COVID-19 started in 2019 with pneumonia cases of unknown etiology in the city of Wuhan, Hubei Province [2]. Despite strict measures, the spread of COVID-19 could not be stopped, and COVID-19 spread to all continents and countries. COVID-19 has so far caused over 215 million cases and over 4.5 million deaths [3]. The first case was detected in Turkey at the time of the declaration of a pandemic [4]. Since then, 6 million cases of COVID-19 and 52,860 deaths have been recorded [5].

COVID-19 is transmitted through surfaces, respiratory droplets, and close contact with an infected person [6]. The household is an ideal place for the spread of SARS-CoV-2 considering the transmission characteristics, the frequency of close contact, the length of time spent, and the fact that it is a closed space. Households offer unique opportunities for transmission of the disease. Households facilitate identification and contact-tracing [7]. At the same time, information may be obtained about the factors affecting the susceptibility of the contacts and the contagiousness of the primary case (PC) [8]. The secondary attack rate (SAR) can be calculated with the data obtained from households. The World Health Organization (WHO) recommended that priority should be given to studies that identify risk factors for the transmission of COVID-19 [9]. Determining the factors that are effective in transmission and determining the characteristics of transmission in the household would provide useful information for preventing the spread of the disease. However, to date, there are no studies that report the characteristics of household or community-based COVID-19 transmission among the Turkish population. At the same time, there are few studies examining the characteristics of COVID-19 in household transmission. The aim of this study is to determine the factors that are effective in transmission within the household, to calculate the household SAR, to determine the factors that affect the susceptibility of the contacts, and the infectivity of the PC.

Methodology

Research questions

The study aimed to investigate three research problems: What is the household secondary attack rate? What are the factors affecting the contagiousness of SARS-CoV-2 in the PC? What factors affect susceptibility to SARS-CoV-2 in adult contacts who were living in the same household?

Study type and population

The cross-sectional study was conducted in Afyonkarahisar, Turkey. Afyonkarahisar has 170,266 households with more than one person. The sample size representing these households was determined as at least 698 households with 97% confidence, 5% deviation, 45% SAR, and 1.5 design effect. The expected SAR was used as 45%, the highest value in the meta-analysis.

Questionnaire and data collection

Data were collected with a questionnaire designed based on the research questions. The questionnaire consisted of 45 questions concerning the characteristics of the household, personal traits, and habits of those living in the household, disease characteristics of those who had COVID-19, and their behaviour in the household during the illness. The questionnaire was tested with a pre-application and was evaluated to be comprehensible.

Households with more than one person and with positive SARS-CoV-2 Polymerase Chain Reaction (PCR) cases, during the period of August 24-31, 2020, were included in the study. Data were collected retrospectively by phone in the period between September 15th – November 30th, 2020. First, the number of people living in the household and their COVID-19 status were determined. The questionnaire was applied to households older than 18 years of age.

Inclusion and exclusion criteria

Households with only one person were excluded. Inclusion criteria for PC required the person to be aged 18 years and over, to have positive SARS-CoV-2 PCR result, to be the first person in the household to have the disease, and at least 48 hours to have passed after the onset of symptoms (to exclude illness from a common source). Secondary case inclusion criteria were onset of symptoms 2-14 days after the onset of symptoms in the PC. Inclusion criteria for the negative group required either a negative COVID-19 PCR test result or no symptoms, or no COVID-19 PCR test result. The numbers related to the disease of those younger than 18 years of age were used only in the calculation of SAR.

Ethics

Prior to performing the research, permission was obtained from the TCSB General Directorate of Health Services COVID-19 Scientific Research Evaluation Commission and Afyonkarahisar Health Sciences University Clinical Research Ethics Committee (2020/11-434). The purpose of the study and confidentiality of the personal information were explained to the participants. Participants who gave consent were included in the study.

Statistical analysis

The participants were divided into two groups. The positives consisted of those with positive PCR test, and the negatives, of those with either a negative PCR test or who did not perform a PCR test. Case definitions, SARS-CoV-2 PCR test information, and diagnostic algorithms determined by the Republic of the Turkey Ministry of Health (TCSB) were used for the diagnosis of COVID-19 [4]. In the diagnostic algorithm, at least one symptom and contact history or two and more symptoms were required for testing.

The research data were evaluated in three stages. In the first stage, SAR was calculated for all the households. In the second stage, the effect of the characteristics of the PC on SAR was evaluated. Thus, the factors affecting the contagiousness of the PC were determined. In the third stage, the factors affecting susceptibility of the adults living in the household were evaluated.

Categorical variables were compared with the Chi-Square Test. The variables with significant differences from categorical variables and socio-demographic characteristics as confounding factors were evaluated with multiple logistic regression analysis (MLRA). Body mass index (BMİ) was calculated based on the participant's reported height and weight. A p-value < 0.05 were considered statistically significant.

Table 1. Correlation between personal, sociodemographic, and household characteristic variables of the primary case and household secondary attack rate of COVID-19.

	Primary Case	Household Contact	Secondary Case	Secondary Attack Rate	Chi Square Test		Multiple Logistic Regression[1]		
	n (%)	n	n	% (95% CI)	χ^2	*p*	OR	95% CI	*p*
Overall	701 (100)	1963	618	31.5 (29.4-33.5)					
Gender of primary case									
Female	390 (55.6)	1077	296	27.5 (24.8-30.2)	17.687	< 0.001	Reference Category		
Male	311 (44.4)	886	322	36.3 (33.1-39.5)			1.459	1.110-1.917	0.007
Age of primary case									
18-59	603 (86.0)	1749	521	29.8 (27.7-31.9)	21.342	< 0.001	Reference Category		
> 59	98 (14.0)	214	97	45.3 (38.6-52.0)			1.384	0.931-2.058	0.108
Education status of primary case									
Illiterate	20 (2.9)	59	11	18.6 (8.7-28.5)	22.573	< 0.001	Reference Category		
Literate	27 (3.8)	80	22	27.5 (17.7-37.3)					
Primary school	265 (37.8)	742	209	28.2 (25.0-31.4)					
Middle School	85 (12.1)	281	81	28.8 (23.5-34.1)					
High school	143 (20.4)	389	129	33.2 (28.5-37.9)			1.510	1.156-1.973	0.003
College / University	161 (23.0)	412	166	40.3 (35.6-45.0)					
Workplace of primary case									
Unemployed / Retired	359 (51.2)	967	314	32.5 (29.5-35.5)	27.383	< 0.001	1.090	0.814-1.461	0.562
Self-employment	80 (11.4)	220	83	37.7 (31.3-44.1)			Reference Category		
Government official	84 (12.0)	222	84	37.8 (31.4-44.2)					
Worker	143 (20.4)	442	121	27.4 (23.2-31.6)					
Farmer	35(5.0)	112	16	14.3 (7.8-20.8)					
İncome status of primary case									
High	95 (13.6)	233	76	32.6 (26.6-38.6)	9.102	0.011	1.051	0.799-1.381	0.724
Middle	463 (66.0)	1272	424	33.3 (30.7-35.9)					
Low	143 (20.4)	458	118	25.8 (21.8-29.8)			Reference Category		
BMI of primary case									
< 25		586	197	33.6 (29.8-37.4)	2.371	0.306	1.128	0.873-1.456	0.358
25-26.9		286	82	28.7 (23.5-33.9)			0.834	0.602-1.155	0.274
> 27		1091	339	31.1 (28.4-33.8)			Reference Category		
Chronic Disease of primary case									
No	518 (73.9)	1478	440	29.8 (27.5-32.1)	8.133	0.004	Reference Category		
Yes	183 (26.1)	485	178	36.7 (32.4-41.0)			1.204	0.924-1.569	0.169
Place of residence									
City	342 (48.8)	921	331	35.9 (32.8-39.0)	29.373	< 0.001	1.778	1.327-2.381	< 0.001
County	191 (27.2)	478	159	33.3 (29.1-37.5)			1.479	1.065-2.054	0.019
Village	168 (24.0)	564	128	22.7 (19.2-26.2)			Reference Category		
Residential structure									
Detached house	319 (45.5)	1002	279	27.8 (25.0-30.6)	12.559	< 0.001	Reference Category		
Apartment	382 (54.5)	961	339	35.3 (32.3-38.3)			1.022	0.780-1.339	0.875
Number of people living in the household (excluding the Primary case)									
1	176 (25.1)	180	82	45.6 (38.3-52.9)	22.767	< 0.001	1.990	1.273-3.112	0.003
2	157 (22.4)	313	114	36.4 (31.1-41.7)			1.333	0.901-1.972	0.151
3	184 (26.3)	552	176	31.9 (28.0-35.8)			1.117	0.778-1.606	0.548
4	101 (14.4)	404	110	27.2 (22.9-31.5)			0.934	0.639-1.364	0.722
5	38 (5.4)	190	48	25.3 (19.1-31.5)			1.118	0.704-1.774	0.636
> 5	45 (6.4)	324	88	27.2 (22.4-32.0)			Reference Category		
Eating with the primary case									
Yes	608 (86.7)	1709	578	33.8 (31.6-36.0)	33.484	< 0.001	1.513	0.919-2.491	0.103
No	93 (13.3)	254	40	15.7 (11.2-20.2)			Reference Category		
Shared rooms with the primary case									
Living room									
Yes	635 (90.6)	1790	599	33.5 (31.3-35.7)	36.961	< 0.001	2.872	1.450-5.688	0.002
No	66 (9.4)	173	19	11.0 (6.3-15.7)			Reference Category		
Bedroom									
Yes	507 (72.3)	1426	475	33.3 (30.9-35.7)	8.071	0.004	1.096	0.826-1.455	0.526
No	194 (27.7)	537	143	26.6 (22.9-30.3)			Reference Category		

[1] The data in Table 1 and Table2 were included in the multiple logistic regression analysis.

Secondary Attack Rate (SAR)

SAR was calculated with the following formula: all positive cases in the household-PC/(Persons in the household-PC) × 100. In the SAR formula, positives excluding the first case living in the household constituted the numerator, and the denominator included all persons living in the household minus the first case.

Results

A total of 701 PCs and 1963 household contacts (HC) were registered for the study. Among them, 34.3% of the HC were children and 65.7% were adults. A total of 1813 participants were contacted, and they included 1112 (86%) HCs and 701 PCs. There was no significant difference between the COVID-19 positivity status of the households to be reached and the

Table 2. Correlation between disease characteristics of the primary case and household secondary COVID-19 attack rate

	Primary Case	Household Contact	Secondary Case	Secondary Attack Rate	Chi Square Test		Multiple Logistic Regression[1]		
	n (%)	n	n	% (95% CI)	χ^2	*p*	OR	95% CI	*p*
Source of illness of the first case									
Working place	138 (19.7)	393	110	28.0 (23.6-32.4)	9.611	0.022	Reference Category		
Friend/Neighbour/Relative	315 (44.9)	882	280	31.7 (28.6-34.8)			1.402	1.002-1.960	0.048
Health institutions	55 (7.9)	147	36	24.5 (17.5-31.5)			0.724	0.439-1.195	0.206
Others	193 (27.5)	541	192	35.5 (31.5-39.5)			1.593	1.123-2.259	0.009
Symptoms of primary case									
Fever									
Yes	508 (72.5)	525	190	36.2 (32.1-40.3)	7.364	0.007	1.225	0.962-1560	0.100
No	193 (27.5)	1438	428	29.8 (27.4-32.2)			Reference Category		
Cough									
Yes	529 (75.5)	501	169	33.7 (29.6-37.8)	1.579	0.209			
No	172 (24.5)	1462	449	30.7 (28.3-33.1)					
Respiratory Distress									
Yes	633 (90.3)	179	52	29.1 (22.4-35.8)	0.54	0.462			
No	68 (9.7)	1784	566	31.7 (29.5-33.9)					
Sore throat									
Yes	503 (71.8)	599	208	34.7 (30.9-38.5)	4.201	0.040	1.134	0.898-1432	0.293
No	198 (28.2)	1364	410	30.1 (27.7-32.5)			Reference Category		
Malaise/fatigue									
Yes	332 (47.4)	1101	354	32.2 (29.4-35.0)	0.522	0.470			
No	369 (52.6)	862	264	30.6 (27.5-33.7)					
Headache									
Yes	526 (75.0)	492	141	28.7 (24.7-32.7)	2.427	0.119			
No	175 (25.0)	1471	477	32.4 (30.0-34.8)					
Vomiting									
Yes	653 (93.2)	112	40	35.7 (26.8-44.6)	0.986	0.321			
No	47 (6.7)	1851	578	31.2 (29.1-33.3)					
Diarrhea									
Yes	627 (89.4)	226	80	35.4 (29.2-41.6)	1.816	0.178			
No	73 (10.4)	1737	538	31.0 (28.8-33.2)					
Application period of primary case									
≤ 3 Day	180 (26.5)	1429	430	30.1 (27.7-32.5)	5.004	0.025	Reference Category		
> 3 Day	498 (73.5)	448	160	35.7 (31.3-40.1)			1.108	0.863-1.422	0.420
Hospitalized primary case									
Yes	87 (12.4)	246	99	40.2 (34.1-46.3)	10.009	0.002	1.239	0.855-1.796	0.257
No	614 (87.6)	1717	519	30.2 (28.0-32.4)			Reference Category		
Spectrum of the primary case's illness									
Asymptomatic	21 (3.0)	48	5	10.4 (1.8-19.0)	29.471	< 0.001	Reference Category		
Mild	408 (58.2)	1127	350	31.1 (28.4-33.8)			3.340	0.375-29.783	0.280
Moderate	179 (25.5)	525	149	28.4 (24.5-32.3)			2.752	0.307-24.699	0.366
Severe	93 (13.3)	263	114	43.3 (37.3-49.3)			4.537	0.495-41.570	0.181
Mask use of the primary case									
Yes	510 (72.8)	1476	389	26.4 (24.2-28.6)	72.511	< 0.001	Reference Category		
No	191 (27.2)	487	229	47.0 (42.6-51.4)			1.590	1.214-2.082	0.001
Appling of isolation of the primary case									
Yes	479 (68.3)	1380	345	25.0 (22.7-27.3)	90.518	< 0.001	Reference Category		
No	222 (31.7)	583	273	46.8 (42.7-50.9)			2.051	1.590-2.646	< 0.001

[1] The data in Table 1 and Table2 were included in the multiple logistic regression analysis.

households reached (χ^2 = 1.976, p = 0.160). Of the participants, 38.7% were PCs, 26.8% were SCs, 14.1% were negative, and 20.5% were not tested. The mean (standard deviation) age, in years, of the participants was 43.61 (14.05) for PCs, 42.79 (16.03) for SCs, 43.16 (16.14) for negatives, and 41.41 (17.29) for non-tested. An average of 3.80 (1.71) people lived in the households and had 3.98 (1.07) rooms.

The SAR was found to be 31.5% (95% Cl: 29.4-33.5). The SAR was 13.7% (95% CI 11.1-16.3) in children and 40.8% (95% CI 38.1-43.5) in adults. SAR was significantly higher in adults (χ^2 = 151.653, p < 0.001). Among adults, the SAR was higher when the

Table 3. Correlation between household contacts' personal, socio-demographic and adherence to disease prevention measures with being COVID-19

	Adult Household Contact	Secondary Case		Chi-Square Test		Multiple Logistic Regression		
	n	n	%	χ^2	p	OR	95% Cl	p
Overall	**1112**	**485**	**43.6**					
Gender of adult household contact								
Female	559	276	49.4	15.158	< 0,001	1.372	1.008-1.867	0.044
Male	553	209	37.8			Reference Category		
Age of adult household contact								
18-59	928	407	43.9	0.314	0.745	1.246	0.837-1.855	0.278
> 59	184	78	42.4			Reference Category		
Education status of adult household contact								
Illiterate	57	18	31.6	13.23	0.021	Reference Category		
Literate	22	6	27.3					
Primary school	344	158	45.9					
Middle School	195	73	37.4					
High school	287	126	43.9			1.415	1.043-1.921	0.026
College / University	207	104	50.2					
Workplace of adult household contact								
Unemployed / Retired	645	297	46.0	18.978	0.001	Reference Category		
Self-employment	116	44	37.9			0.998	0.614-1.621	0.993
Government official	99	56	56.6			1.554	0.938-2.575	0.087
Worker	195	72	36.9			0.999	0.670-1.490	0.995
Farmer	57	16	28.1			0.885	0.453-1.729	0.721
İncome status of adult household contact								
High	140	65	46.4	11.124	0.004	1.503	1.083-2.085	0.015
Middle	727	336	46.2					
Low	245	84	34.3			Reference Category		
Chronic disease of adult household contact								
No	898	382	42.5	2.197	0.138	0.910	0.640-1.294	0.599
Yes	214	103	48.1			Reference Category		
BMI of adult household contact								
< 20	69	26	37.7	9.934	0.002	Reference Category		
20-24.99	375	147	39.2			1.149	0.649-2.035	0.633
25-29.99	417	182	43.6			1.439	0.811-2.554	0.213
≥ 30	251	130	51.8			1.934	1.059-3.534	0.032
Closeness of household contact with primary case								
Husband and Wife of PC	564	256	45.4	4.363	0.359			
Child of PC	253	103	40.7					
Parent of PC	197	88	44.7					
Sibling of PC	67	29	43.3					
Others	31	9	29.0					
Mask use of the household contacts								
Yes	756	296	39.2	18.419	< 0.001	Reference Category		
No	356	189	53.1			1.554	1.137-2.123	0.006
Appling of quarantine to the household contact								
Yes	710	279	39.3	14.81	< 0.001	Reference Category		
No	402	206	51.2			1.288	0.950-1.744	0.103
Eating with the primary case before COVID-19								
Yes	969	454	46.9	28.722	< 0.001	2.208	1.385-3.521	0.001
No	138	31	22.5			Reference Category		
Shared bedrooms with the primary case before COVID-19								
Yes	623	318	51.0	31.828	< 0.001	1.786	1.351-2.362	<.0.001
No	489	167	34.2			Reference Category		

PC was over 60 years old ($p < 0.001$), but the age of the PC in the MLRA was not associated with an increased risk of infection in the household (Table 1). There was no association between COVID-19 status and the age of adult contacts ($p = 0.745$) (Table 3).

SAR was found to be higher when the PC was male ($p < 0.001$). Being a male PC increased the risk of COVID-19 (OR = 1.459 95% CI: 1.110-1.917) (Table 1). Among the contacts, the positivity rate among women was higher ($p < 0.001$). Being a female contact increased the risk of COVID-19 (OR = 1.372, 95% CI: 1.008-1.867) (Table 3).

Increase in the education level of the PC ($p < 0.001$) and the HC ($p = 0.021$) led to increased COVID-19 infection in the household ($p < 0.001$). High school and higher education of the PC (OR = 1.510, 95% CI: 1.156-1.973) and the HC (OR = 1.415, 95% CI: 1.043-1.921) increased the risk of COVID-19 in the household (Table 1, Table 3).

When the characteristics of the household were evaluated, living in the city (OR = 1.778, 95% Cl: 1.327-2.381) or county (OR = 1.479, 95% Cl: 1.065-2.054) increased SAR. The SAR of apartment household was higher than detached households ($p < 0.001$). The SAR was the highest in the households with one HC ($p < 0.001$) and the risk of infection was increased (OR = 1.990, 95% Cl: 1.273-3.112) (Table 1).

The SAR increased if there was a shared living room ($p < 0.001$) and bedroom ($p = 0.004$), in the household. In the case of MLRA, shared living room increased the risk of disease (OR = 2.872, 95% Cl: 1.450-5.688) (Table 1).

SAR distribution among the PC differed by occupation and income status ($p < 0.001$), but this was not the case with MLRA (Table 1). When the occupations of the HC were compared; it was observed that the highest COVID-19 positivity percentage was among civil servants and the lowest COVID-19 positivity percentage was among farmers ($p = 0.001$). Occupation of the HC was not associated with increased COVID-19 risk in the MLRA. The risk of COVID-19 (OR = 1.503, 95% CI: 1.083-2.085) was higher in the HC with medium and good income (Table 3).

No significant difference was found between SAR and BMI of the PC ($p = 0.306$) (Table 1). The positivity rate increased with the increase in BMI ($p = 0.002$) and the risk of COVID-19 increased in the HC with BMI ≥ 30 (OR = 1.934, 95% CI: 1.059-3.534) (Table 3).

Chronic diseases of the PC increased the SAR ($p = 0.004$), but the chronic diseases did not affect the SAR in MLRA (Table 1). On the other hand, chronic disease had no effect on positivity rates among the HC (Table 3).

The risk of COVID-19 increased when the source of the disease of the PC was a friend, neighbour, or relative (OR = 1.402, 95% Cl: 1.002-1.960) as compared to Others (OR = 1.593, 95% Cl: 1.123-2.259) (Table 2). There was no difference between the closeness of the HC with the PC and having COVID-19 ($p = 0.359$) (Table 3).

The SAR was higher in the PC with fever ($p = 0.007$) or sore throat ($p = 0.040$). However, fever and sore throat had no effect on the SAR in MLRA (Table 2).

When the PC went to the hospital four days after the first symptom onset, the SAR was higher than those who went to the hospital earlier ($p = 0.025$). The SAR was higher in households of hospitalized or "Severe" PC ($p = 0.002$). The SAR was lowest in asymptomatic COVID-19 patients ($p < 0.001$) (Table 2).

SAR was higher when the PC did not use a mask after the diagnosis of the disease ($p < 0.001$). At the same time, the percentage of positivity was higher when the HC did not use masks when infected with COVİD-19 ($p < 0.001$). The risk of COVID-19 increased when the PC (OR = 1.590, 95% Cl: 1.214-2.082) and the HC (OR = 1.554, 95% Cl: 1.137-2.123) did not use masks while infected (Table 2, Table 3).

SAR was higher when the PC did not adhere to isolation ($p < 0.001$) and the risk of COVID-19 was increased (OR = 2.051, 95% CI: 1.590-2.646) (Table 2). When the HC did not comply with the quarantine, then there was a higher percentage of positivity ($p < 0.001$), but it was not a factor that increased the risk of COVID-19 in the MLRA (Table 3).

Discussion

In this study, household SAR was found to be 31.5%. In a meta-analysis, the SAR of SARS-CoV-2 was calculated as 16.6% and ranged from 0.00% to 45.0% [10]. The SAR value in this study was similar to the SAR calculated from studies in countries such as the United States, United Kingdom, and Israel; however, it was higher than the SAR in studies based in China, Korea, and India [10]. The variation in SAR between studies was due to differences in contact screening strategies, culture, and disease control measures among the communities studied.

In Turkey, symptom-based COVID-19 screening was implemented. However, the high SAR in our study indicates that symptom-based screening was as effective as other screening methods. As the COVID-19 measures increased, the SAR decreased [11]. The high SAR in this study may be associated with collection of data at a time when the fewer precautions were being taken.

In our study, SAR of children was lower than that of adults. This result was consistent with the results of the studies in which the relationship between age and SAR was investigated [10,12,13]. Madewell *et al*. [10] stated that children's household SAR was 16.8% and that of the adults was 28.3%. Children's susceptibility to SARS-Cov-2 is 43% of that of adults. They concluded that children's SAR was low since they had the disease asymptomatically or with mild symptoms, so they were not diagnosed and they were also less susceptible to SARS-CoV-2 infection [13].

In adults, the SAR increased in households of PC older than 60 years old. Similar results were obtained in studies examining the relationship between age and COVID-19 [11,14]. Age was associated with increased viral load and ribonucleic acid (RNA) shedding in the upper respiratory tract [15].

The SARS-CoV positivity risk was higher in households where the PC was male. However, in some studies, there was no relationship between gender and contagiousness [11,16,17]; while there was a relationship between male gender and contagiousness in another study [18]. Longer period of viral RNA shedding [15] and severe symptoms [19] in men, coupled with behavioural differences between male and female patients [18] had an effect on the contagiousness of the disease. Increase in susceptibility to the disease in women was also effective in the increase in SAR. The fact that women were more susceptible to COVID-19 than men [19,20], was associated with an increased SAR. In the current study, the COVID-19 positivity risk was higher among the women. The increase in susceptibility to COVID-19 might be related to the fact that women usually undertake household chores, cook, and take care of children in the Turkish family structure and as a result they had extensive contact with COVID-19 cases at home.

SAR in the household increased with increase in the education level of the PC. This was especially the case when education was higher than middle school, and there was an increased risk of both contagiousness and susceptibility to disease. There was a positive relationship between health literacy [21], risk perception [22], and education level. Health literacy involves recognizing the importance of a situation and taking measures to protect oneself and others [23]. One of the measures that can be taken for COVID-19 is to reduce the transmission of the disease by early diagnosis [24]. The effect of education, low health literacy, and low-risk perception would cause them to attribute mild symptoms to non-COVID-19 illness and not contact healthcare institutions. Thus, the lower educational status caused lower positivity.

The rate of positive tests was higher among the obese [25,26]. In this study, the positivity rates of the HC increased with the increase in Body Mass Index (BMI); the risk was highest, when the BMI was over 30. Chronic diseases accompanying obesity, dysfunctions in metabolic pathways, and changes in the immune system increased the risk of COVID-19 [27].

The SARS-CoV-2 transmission is known to increase in crowded environments [25,28]. In this study, SARS-CoV positivity risk was higher when the HC lived in cities and towns, than in villages. SAR was higher in households of PC living in apartments than those living in detached houses. Characteristics of the residences and differences in living conditions in villages, towns, and cities might influence this difference.

SAR decreased as the number of people living in a household increased. This result was similar to the results obtained from other studies [10,11,18,25]. In addition, the number of children was higher in crowded households. Children get the disease asymptomatically or with mild symptoms, and consequently they are not diagnosed. They are also less susceptible to SARS-CoV-2 infection [13]. Therefore, the increased number of children in crowded households may be associated with a decrease in secondary attack rate and risk.

In this study, SAR was higher when the PC had symptoms of fever or sore throat. Symptoms such as fever [20,29], expectoration [29], dizziness, myalgia, and chills [20] were associated with contagiousness. Fever was associated with negative clinical course and severity of the disease [30]. As the severity of the disease increased, the contagiousness increased [20].

Households where the PC was diagnosed three days after symptom onset had higher SAR than those with an earlier diagnosis. Studies on the transmission characteristics of SARS-CoV-2 have demonstrated an increasing relationship between increased contact time and contagiousness [14,20,31]. Viral RNA particles can be detected in mucus swab samples on the first day of SARS-CoV-2 infection in primates, the viral RNA in exhaled particles increased from the third day, and continued to increase until the seventh day; thereafter the viral particles declined and were not detected on the fourteenth day [32]. A meta-analysis examining viral load dynamics reported that viral RNA in the upper respiratory tract peaked in the first week of the disease and no live virus was detected after the ninth day [15].

Based on this data, SARS-CoV-2 is transmitted in early days of infection, the transmission started to increase from the third day, reached its peak on the seventh day, and was not transmitted after the ninth day. Therefore, early diagnosis and early isolation measures would be effective in reducing contagion.

The contagion was less in asymptomatic COVID-19 patients [10,11,33]. In this study, SAR was lower in households of PC of asymptomatic patients. Studies investigating the dynamics of COVID-19 have concluded that the viral loads of asymptomatic and symptomatic patients were similar, but the viral load decreased more rapidly in asymptomatic patients [15]. The decline in viral load reduced the time that the patient was contagious, causing the disease to spread to fewer people. SAR was found to be higher in households of hospitalized PC who stated that they had severe illness. Viral shedding was higher and the duration of the transmission was longer in those with severe disease [15]. This would cause an increase in SAR. Although isolation was provided for the household of hospitalized patients, high SAR indicated that the disease was transmitted prior the hospitalization.

Eating with the PC, sleeping in the same room, and sharing rooms were found to be associated with increased household SAR. These features indicated the contact intensity of HC with the PC. The disease was transmitted more in households with higher contact density with the PC; thus, contact density was an effective factor in household transmission [34].

During the COVID-19 pandemic, people started to take measures such as wearing masks and social distancing to protect themselves when they are around others. However, these measures were usually not applied in the household [20]. It was observed that both the PC and the use of masks by contacts were associated with a decrease in household SAR after the illness. Use of masks after being infected with COVID-19 reduced the spread of the disease in the household [31]. However, the use of masks was a more effective method, especially in households prior to the spread of infection [17], since the disease is highly contagious in the early stages of the disease.

In our study, households who had adopted isolation or quarantine methods were more effective in preventing spread of the disease than households who did not implement complete isolation/quarantine measures from one another. When the case and his/her contacts are completely isolated or quarantined from the rest of the household [11,35], the household transmission was reduced. However, in our study, we found that reduced transmission could not be achieved due to the ineffective use of isolation and quarantine measures, inconsistent application of masks, or because of the spread of infection before any of these measures were taken.

Conclusions

It is concluded that SAR is higher in Turkey than in other countries and there was limited compliance with quarantine and isolation measures. Household transmission can be reduced by interventions such as masks, isolation, and quarantine. The transmission of COVID-19 in households can be reduced if preventive measures are taken in the early stages of infection.

Limitations of the study

The study was carried out during summer, and seasonal effects may be seen in the results. PCR test result of all participants was not available. It was possible that these participants had the disease asymptomatically or with very mild symptoms. Including serological tests may have contributed to the accuracy of the results. Data on the socio-demographic characteristics and disease characteristics of those under the age of eighteen were not collected. The contact characteristics obtained could not be generalized to those younger than eighteen years old.

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Corresponding author

Yiğit Şenol MD
Afyonkarahisar Health Directorate
03030, Afyonkarahisar, Turkey.
Tel: +90 4440430
Fax: +90 272 2147524
Email: dryigitsenol@hotmail.com

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